PB90-256405

Guides to Pollution Prevention: The Paint Manufacturing Industry

Jacobs Engineering Group, Inc., Pasadena, CA

Prepared for:
Environmental Protection Agency, Cincinnati, OH

Jun 90

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before complet

1. REPORT NO. EPA/625/7-90/005	2.
3. PB90-256405	
4. TITLE AND SUBTITLE GUIDES TO POLLUTION:The Paint Manufacturing Industry	5. REPORT DATE
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Jacobs Engineering Group, Inc.	8. PERFORMING ORGANIZATION REPORT NO
9. PERFORMING ORGANIZATION NAME AND ADDRESS Jacobs Engineering Group, Inc. Pasadena, California 91101-3063	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO. 68-02-4286
12. SPONSORING AGENCY NAME AND ADDRESS Risk Reduction Engineering Laboratory--Cincinnati, OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, OH 45268	13. TYPE OF REPORT AND PERIOD COVERED
	14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES Project Officer: Lisa M. Brown 513/569-7634 FTS 684-7634

16. ABSTRACT

Paint manufacturing facilities generate large quantities of both hazardous and nonhazardous wastes. These wastes are: equipment cleaning wastewater and waste solvent, filter cartridges, off-spec paint, spills, leftover containers; and pigment dusts from air pollution control equipment. Reducing the generation of these wastes at the source, or recycling the wastes on- or off-site, will benefit paint manufacturers by reducing raw material needs, reducing disposal costs; and lowering the liabilities associated with hazardous waste disposal. This guide provides an overview of the paint manufacturing processes and operations that generate waste and presents options for minimizing this waste generation through source reduction or recycling.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 72
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

United States
Environmental Protection
Agency

Risk Reduction Engineering Laboratory
Center for Environmental Research Information
Cincinnati, Ohio 45268

EPA/625/7-90/005
June 1990

PB90-256405

Technology Transfer

EPA

Guides to Pollution Prevention

The Paint Manufacturing Industry

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA 22161

EPA /625/7-90/005
June 1990

GUIDES TO POLLUTION PREVENTION:
The Paint Manufacturing Industry

RISK REDUCTION ENGINEERING LABORATORY
AND
CENTER FOR ENVIRONMENTAL RESEARCH INFORMATION
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

NOTICE

This guide has been subjected to U.S. Environmental Protection Agency's peer and administrative review and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. This document is intended as advisory guidance only to paint manufacturers in developing approaches for pollution prevention. Compliance with environmental and occupational safety and health laws is the responsibility of each individual business and is not the focus of this document.

Worksheets are provided for conducting waste minimization assessments of paint manufacturing facilities. Users are encouraged to duplicate portions of this publication as needed to implement a waste minimization program.

FOREWORD

Paint manufacturing facilities generate large quantities of both hazardous and nonhazardous wastes. These wastes are equipment cleaning wastewater and waste solvent, filter cartridges, off-spec paint spills, leftover containers, and pigment dusts from air pollution control equipment. Reducing the generation of these wastes at the source or recycling the wastes on- or off-site will benefit paint manufacturers by reducing raw material needs, reducing disposal costs, and lowering the liabilities associated with hazardous waste disposal.

This guide provides an overview of the paint manufacturing processes and operations that generate waste and presents options for minimizing waste genration through source reduction and recycling.

ACKNOWLEDGMENTS

This guide is based in part on waste minimization assessments conducted by Jacobs Engineering Group Inc., Pasadena, California, for the California Department of Health Services (DHS). Contributors to these assessments include: David Leu, Benjamin Fries, Kim Wilhelm, and Jan Radimsky of the Alternative Technology Section of DHS. Much of the information in this guide that provides a national perspective on the issues of waste generation and minimization for paint manufacturers was provided originally to the U.S. Environmental Protection Agency by Versar, Inc. and Jacobs Engineering Group Inc. in "Waste Minimization-Issues and Options, Volume II, " Report No. PB87-114369 (1986). Jacobs Engineering Group Inc. edited and developed this version of the waste minimization assessment guide under subcontract to Radian Corporation (USEPA Contract 68-02-4286).

Lisa M. Brown of the U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, was the project officer responsible for the preparation and review of this document . Harry Freeman, Risk Reduction Engineering Laboratory, EPA; Benjamin Fries, DHS; Jerry Kohl, Department of Nuclear Engineering, North Carolina State University; Robert Nelson, National Paint and Coatings Association, Washington, D.C.; Joe Seaton, Lilly Industrial Coatings, Montebello, California; and Arnold Hoffman, Major Paint Co., Torrance, California contributed and served as reviewers of this guide.

CONTENTS

SECTION	PAGE
Notice	ii
Foreword	iii
Acknowledgments	iv
1. Introduction	1
2. Paint Manufacturing Industry Profile	5
3. Waste Minimization Options for Paint Manufacturers	9
4. Guidelines for using the Worksheets	14
APPENDIX A: Case Studies of Paint Manufacturing Plants	30
APPENDIX B: Where to Get Help; Further Information on Waste Minimization	63

SECTION 1
INTRODUCTION

This guide is designed to provide paint manufacturers with waste minimization options appropriate for this industry. It also provides worksheets designed to be used for a waste minimization assessment of a paint manufacturing facility, to develop an understanding of the facility's waste generating processes and to suggest ways that the waste may be reduced. Besides paint manufacturing plant operators and environmental engineers, this document may be useful to our regulatory agency representatives and consultants.

The worksheets and the list of waste minimization options were developed through assessments of two Los Angeles area paint manufacturing firms commissioned by the California Department of Health Services (Calif. DHS 1987). The two firms' operations, manufacturing processes, and waste generation and management practices were surveyed, and their existing and potential waste minimization options were characterized. Economic analyses were performed on selected options.

Reducing waste is a high priority for the paint manufacturing industry. In 1981, U.S. paint, coating, and ink manufacturers represented 44 percent of the market for solvents (Pace 1983). Solvents are used in the industry as carriers for resins and pigments and to clean the various process equipment used for production. Although cleaning solvents are often distilled and reused, a residual paint sludge remains, which contains solvents and in some cases, toxic metals such as mercury, lead and chromium. Depending on the constituents, the wastes could be considered RCRA wastes F002 (halogenated solvents), F003 (non-halogenated solvents such as acetone and xylene), F004 (non-halogenated solvents such as cresols, cresylic acid, nitrobenzene, and solvent blends), or F005 (non-halogenated solvents such as toluene, methyl ethyl ketone, and benzene). These wastes are currently banned from land disposal.

The amount of wastes disposed of by paint manufacturers is high. For example, in 1984 the paint manufacturing industry in California disposed of 21,000 tons of solvent bearing waste off-site, making this industry the highest-volume generator of manifested solvent wastes in that year (ICF 1986).

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Wastes Amendments to the Resource Conservation and Recovery Act (RCRA). As the federal agency responsible for writing regulations under RCRA, the U.S. Environmental Protection Agency (EPA) has an interest in ensuring that new methods and approaches are developed for minimizing hazardous waste and that such information is made available to the industries concerned. This guide is one of the approaches EPA is using to provide industry-specific information about hazardous waste minimization.

The options and procedures outlined can also be used in efforts to minimize other wastes generated in a facility. EPA has also developed a general manual for waste minimization in industry. The *Waste Minimization Opportunity Assessment Manual (USEPA 1988)* tells how to conduct a waste minimization opportunity assessment and develop options for reducing hazardous waste generation at a facility. It explains the management strategies needed to incorporate waste minimization into company policies and structure, how to establish a company-wide waste minimization program, conduct assessments, implement options, and make the program an on-going one. The elements of waste minimization assessment are explained in the Overview, next section.

In the following sections of this manual you will find:

- An overview of the paint manufacturing industry and the processes used by the industry (Section Two);
- Waste minimization options for paint manufacturers (Section Three);
- Waste Minimization Assessment Guidelines and Worksheets (Section Four)
- An Appendix, containing:
  - Case studies of waste generation and waste minimization practices of two paint manufacturers;
  - Where to get help: additional sources of information.

Overview of Waste Minimization Assessment

In the working definition used by EPA, waste minimization consists of *source reduction* and *recycling*. Of the two approaches, source reduction is usually considered preferable to recycling from an environmental perspective. *Treatment* of hazardous waste is considered an approach to waste minimization by some states but not by others, and thus is not addressed in this guide.

A Waste Minimization Opportunity Assessment (WMOA), sometimes called a waste minimization audit, is a systematic procedure for identifying ways to reduce or eliminate waste. The steps involved in conducting a waste minimization assessment are outlined in Figure 1 and presented in more detail in the next paragraphs. Briefly, the assessment consists of a careful review of a plant's operations and waste streams and the selection of specific areas to assess. After a particular waste stream or area is established as the WMOA focus, a number of options with the potential to minimize waste are developed and screened. The technical and economic feasibility of the selected options are then evaluated. Finally, the most promising options are selected for implementation.

To determine whether a WMOA would be useful in your circumstances, you should first read this section describing the aims and essentials of the WMOA process. For more detailed information on conducting a WMOA, consult the *Waste Minimization Opportunity Assessment Manual*.

The four phases of a waste minimization assessment are:

- Planning and organization
- Assessment phase
- Feasibility analysis phase
- Implementation

PLANNING AND ORGANIZATION

Essential elements of planning and organization for a waste minimization program are: getting management commitment for the program; setting waste minimization goals; and organizing an assessment program task force.

ASSESSMENT PHASE

The assessment phase involves a number of steps:

- Collect process and facility data
- Prioritize and select assessment targets
- Select assessment team
- Review data and inspect site
- Generate options
- Screen and select options for feasibility study

Collect process and facility data. The waste streams at a facility should be identified and characterized. Information about waste streams may be available on hazardous waste manifests, National Pollutant Discharge Elimination System (NPDES) reports, routine sampling programs and other sources.

Developing a basic understanding of the processes that generate waste at a facility is essential to the WMOA process. Flow diagrams should be prepared to identify the quantity, types and rates of waste generating processes. Also, preparing material balances for various processes can be useful in tracking various process components and identifying losses or emissions that may have been unaccounted for previously.

Prioritize and select assessment targets. Ideally, all waste streams in a facility should be evaluated for potential waste minimization opportunities. With limited resources, however, a plant manager may need to concentrate waste minimization efforts in a specific area. Such considerations as quantity of waste, hazardous properties of the waste, regulations, safety of employees, economics, and other characteristics need to be evaluated in selecting a target stream.

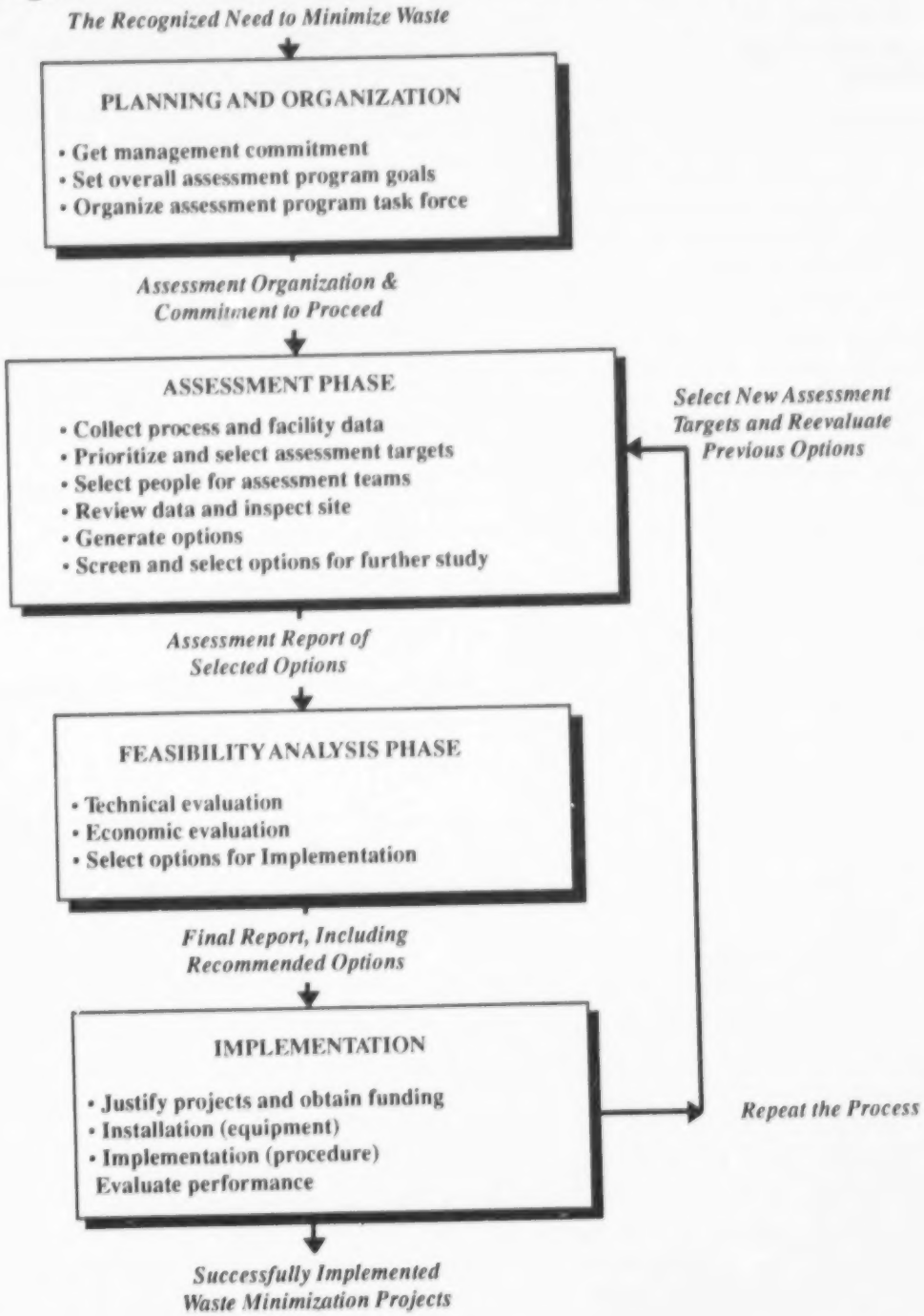
Select assessment team. The team should include people with direct responsibility and knowledge of the particular waste stream or area of the plant.

Review data and inspect site. The assessment team evaluates process data in advance of the inspection. The inspection should follow the target process from the point where raw materials enter the facility to the points where products and wastes leave. The team should identify the suspected sources of waste. This may include the production process; maintenance operations; and storage areas for raw materials, finished product, and work in progress. The inspection may result in the formation of preliminary conclusions about waste minimization opportunities. Full confirmation of these conclusions may require additional data collection, analysis, and/or site visits.

Generate options. The objective of this step is to generate a comprehensive set of waste minimization options for further consideration. Since technical and economic concerns will be considered in the later feasibility step, no options are ruled out at this time. Information from the site inspection, as well as trade associations, government agencies, technical and trade reports, equipment vendors, consultants, and plant engineers and operators may serve as sources of ideas for waste minimization options.

Both source reduction and recycling options should be considered. Source reduction may be accomplished through:

Figure 1. The Waste Minimization Assessment Procedure


The Recognized Need to Minimize Waste
PLANNING AND ORGANIZATION
• Get management commitment
• Set overall assessment program goals
• Organize assessment program task force
Assessment Organization & Commitment to Proceed
ASSESSMENT PHASE
• Collect process and facility data
• Prioritize and select assessment targets
• Select people for assessment teams
• Review data and inspect site
• Generate options
• Screen and select options for further study
Select New Assessment Targets and Reevaluate Previous Options
Assessment Report of Selected Options
FEASIBILITY ANALYSIS PHASE
• Technical evaluation
• Economic evaluation
• Select options for Implementation
Final Report, Including Recommended Options
IMPLEMENTATION
• Justify projects and obtain funding
• Installation (equipment)
• Implementation (procedure)
Evaluate performance
Repeat the Process
Successfully Implemented Waste Minimization Projects

- Good operating practices
- Technology changes
- Input material changes
- Product changes

Recycling includes:

- Use and reuse of waste
- Reclamation

Screen and select options for further study. This screening process is intended to select the most promising options for full technical and economic feasibility study. Through either an informal review or a quantitative decision-making process, options that appear marginal, impractical or inferior are eliminated from consideration.

FEASIBILITY ANALYSIS

An option must be shown to be technically and economically feasible in order to merit serious consideration for adoption at a facility. A technical evaluation determines whether a proposed option will work in a specific application. Both process and equipment changes need to be assessed for their overall effects on waste quantity and product quality. Also, any new products developed through process and/or raw material changes need to be tested for market acceptance.

An economic evaluation is carried out using standard measures of profitability, such as payback period, return on investment, and net present value. As in any project, the cost elements of a waste minimization project can be broken down into capital costs and economic costs. Savings and changes in revenue also need to be considered.

IMPLEMENTATION

An option that passes both technical and economic feasibility reviews should then be implemented at a facility. It is then up to the WMOA team, with management support, to continue the process of tracking wastes and identifying opportunities for waste minimization, throughout a facility and by way of periodic reassessments. Either such ongoing reassessments or an initial investigation of waste minimization opportunities can be conducted using this manual.

References

Calif. DHS. 1987. *Waste Audit Study: Paint Manufacturing Industry.* Report prepared by Jacobs Engineering Group Inc., Pasadena, Calif., for the California Department of Health Services, Alternative Technology Section, Toxic Substances Control Division, April 1987.

ICF Consulting Associates, Jacobs Engineering Group, and Versar. 1986. *Guide to Solvent Waste Reduction Alternatives.* Prepared for California Department of Health Services, Alternative Technology and Policy Development Section, October 10, 1986.

Pace Company Consultants and Engineers, Inc. 1983. *Solvent Recovery in the United States 1980-1990.* Houston, Texas.

USEPA. 1988. *Waste Minimization Opportunity Assessment Manual.* Hazardous Waste Engineering Research Laboratory, Cincinnati, Ohio, EPA/625/7-88//003.

SECTION 2
PAINT MANUFACTURING INDUSTRY PROFILE

Industry Description

As defined by Standard Industrial Classification (SIC) 2851, the paints and allied products industry "comprises establishments primarily engaged in the manufacture of paints (in paste and ready mixed form), varnishes, lacquers, enamels and shellacs, putties, wood fillers and sealers, paint and varnish removers, paint brush cleaners, and allied paint products." Establishments engaged in the manufacture of pigments (organic or inorganic), resins, printing inks, adhesives and sealants, or artist materials are not included.

The industry is comprised of roughly 1,375 establishments nationwide. Approximately 44 percent of all paint manufacturing plant sites are located in five states (California, New Jersey, New York, Illinois, and Ohio), with 67 percent being located in ten states. Most of the plants are located near major population centers.

Products and Their Uses

Most small plants produce paint in 10 to 500 gallon batches. Plants with more than 20 employees produce paint in 200 to 3,000 gallon batches. Overall, the paint industry sold 8.6 billion dollars worth of product in 1983 ($3.9 billion for architectural coatings, $3.0 billion for product coatings, and $1.7 billion for special purpose coatings) (Webber 1984). The amounts and distribution of products manufactured by the paint industry in 1983 are shown in Table 1.

For an average paint plant located in the U.S., 60 percent of its total annual production would be solvent–based paint, 35 percent would be water–based paint, and 5 percent would be allied products. While a large percentage of paint used for architectural coating is water–based (more than 70 percent), solvent–based paint is still predominantly used for product and special purpose coatings.

Table 1. 1983 Paint Products and Use Distribution

Architectural Coatings	463 million gallons
Product Coatings	331 million gallons
Metal containers	19%
Automotive	16%
Machinery	6%
Sheet, strip and coil	6%
Metal furniture	5%
Other	48%
Special Purpose Coatings	130 million gallons
High performance maintenance	31%
Automotive and machinery refinishing	29%
Traffic paint	14%
Other	26%

Source: Chemical and Engineering News (Webber 1984).

Raw Materials

Annual consumption rates of raw materials used by the paint manufacturing industry are shown for 1982 in Table 2.

The major raw materials used to manufacture paint are resins, solvents, drying oils, pigments, and extenders. Based on the wide variety of paints produced, no one type of material dominates the market.

Process Description

Detailed process flow diagrams of paint manufacturing have been presented in the open literature (Haines 1954, Payne 1961). The following description briefly highlights the production of the industry's two main products: solvent–based paint and water–based paint. At a typical plant, both types of paint are produced. A block flow diagram of the steps involved in manufacturing paint is presented in Figure 2.

Table 2. Raw Materials Used by the Paint Manufacturing Industry in 1982

Materials	Usage
Resins	1844 million lbs/yr.
Alkyd	33%
Acrylic	19%
Vinyl	19%
Other	29%
Solvents	3774 million lbs/yr.
Aromatic	30%
Aliphatic	27%
Ketones	17%
Alcohols	12%
Other	14%
Pigments	1062 million lbs/yr.
Titanium dioxide	65%
Inorganic(a)	33%
Organic	2%
Extenders	1162 million lbs/yr.
Calcium carbonate	31%
Talc	25%
Clay	23%
Other	21%
Miscellaneous	220 million lbs/yr.
Drying oils	41%
Plasticizers	18%
Other	41%

Source: Chemical Economics Handbook (SRI 1981) data for 1977 adjusted for 1982 production rates.

(a) Approximately 60 percent of the inorganic pigments used consisted of iron oxide, zinc oxide, zinc dust, and aluminum paste; 27 percent consisted of lead and chrome compounds; and 13 percent consisted of other compounds.

The production of solvent–based paint begins by mixing some of these: resins, dry pigment, and pigment extenders, in a high speed mixer. During this operation, solvents and plasticizers are also added. Following the mixing operation, the batch frequently is transferred to a mill for additional grinding and mixing. The type of mill is dependent on the types of pigments being handled, so that no one style is universal. Next, the paint base or concentrate is transferred to an agitated tank where tints and thinner (usually a volatile naphtha or blend of solvents) and the balance of the resin are added. Upon reaching the proper consistency, the paint is filtered to remove any non-dispersed pigment and transferred to a loading hopper. From the hopper, the paint is poured into cans, labeled, packed, and moved to storage.

The water-based paint process is very similar to the solvent-based process. The major difference is the substitution of water for solvent and the sequencing of material additions. Preparation of water-based paint begins by mixing together water, ammonia, and a dispersant in a mixer. To this mixture, dry pigment and pigment extenders are added. After mixing, the material is ground in a mill and then transferred to an agitated mix tank. Four additions of materials occur in this tank. First, resin and plasticizers are added to the mixture; second, a preservative and an antifoaming agent are added; third, a polyvinyl acetate emulsion is added; and fourth, water is added as a thinner. Following this mixing operation, the handling of the paint is similar to that for solvent-based paints. At many facilities the grinding and the mixing and grinding operation may be bypassed with all the dispersion operations occurring in a single high-speed mixer.

Waste Description

Typically, paint facilities segregate and store waste only to the degree required by the waste disposal contractor. Since the degree of segregation can affect the amount of material having to be classified as hazardous, and the cost of disposing of hazardous material is increasing, paint facilities are taking a more active role in waste management. The major wastes that the paint industry must manage are empty raw material packages, dust from air pollution control equipment, off-specification paint, spills,

Figure 2. Block Flow Diagram for Paint Manufacture

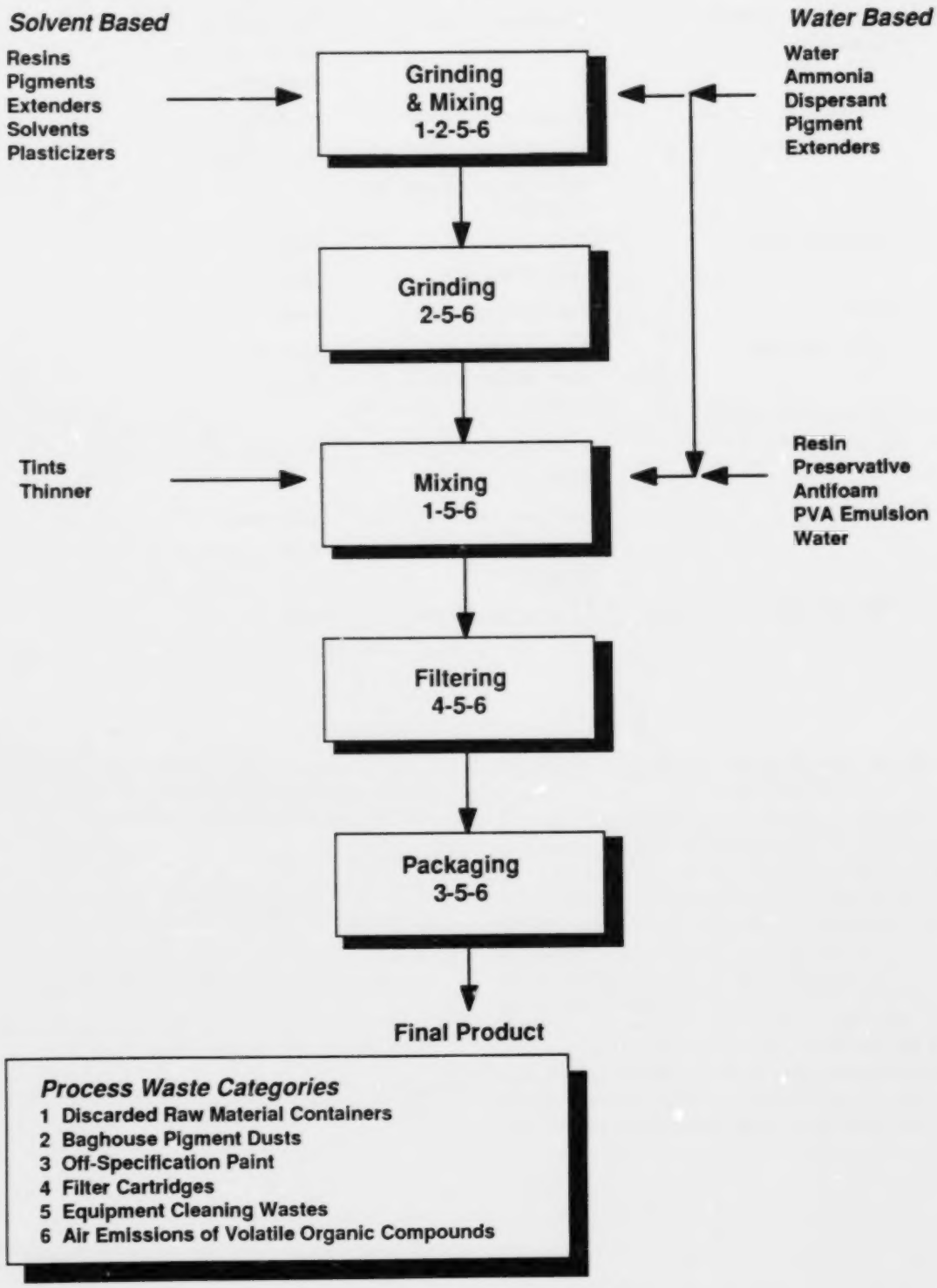


Table 3. Paint Manufacturing Process Wastes

No	Waste Description	Process Origin	Composition	RCRA Codes
1.	Leftover raw materials containers	Unloading of materials into mixing tanks	Paper bags with a few ounces of left over pigments	---
2.	Pigment dusts from air	Unloading of pigment	Pigments	---
3.	Volatile organic compounds	Air emissions from storage tanks and open processing equipment.	Resins, solvent	---
4.	Off-specification	Color matching(small scale) production	Paint Paint	--- ---
5.	Spills	Accidential discharge	Paint	---
6.	Waste rinsewater	Equipment cleaning using water and/or caustic solutions	Paint, water, caustic	---
7.	Waste solvent	Equipment cleaning using solvent	Paint, solvent	F002 F003
8.	Paint sludge	Equipment cleaning sludges removed from cleaing solution	Paint, water, caustic, solvent	---
9.	Filter cartridges	Undispersed pigment	Paint	---

and equipment cleaning wastes. Equipment cleaning wastes are a dominant waste stream.

The primary specific wastes associated with paint manufacturing are listed in Table 3. Wastes generated by the industry are usually managed in one of four ways: on-site reuse, on-site recycling, off-site recycling, and off-site treatment/disposal. On-site reuse involves the reuse of waste (without treatment) as a feed or wash material for producing other batches of paint. Also included is the sale or in-house use of off-specification paint as utility paint. On-site recycling involves the reclaiming of solvent by distillation or recovery of heating values by incineration. Usually, on-site recycling is performed by large companies (those that produce more than 35,000 gallons of solvent waste each year) while small companies (those that produce 20,000 gallons or less per year) send the waste to an off-site recycler. The fourth option, off-site treatment/disposal involves incineration or land disposal.

References

Haines, H.W. (ed.) 1954. *Resin and Paint Production - 1954 Style.* Ind. Eng. Chem. 46(10):2010–22.

Payne, H.F. 1961. *Organic Coating Technology.* 2 volumes. John Wiley & Sons, New York, N.Y.

SRI. 1981. *Chemical Economics Handbook*, 1982. Stanford Research Institute, Menlo Park, Calif.

Webber, D. 1984. Coating industry heading for record year. *Chem. Eng. News* 61(40):51.

SECTION 3
WASTE MINIMIZATION OPTIONS FOR PAINT MANUFACTURERS

Description of Techniques

This section discusses recommended waste minimization methods for paint manufacturers. These methods come from accounts published in the open literature and through industry contacts. The primary waste streams associated with paint manufacturing are listed in Table 4 along with recommended control methods. In order of occurrence at a facility, the waste streams are: equipment cleaning wastes; spills and off spec paint; leftover inorganic pigment in bags and packages; pigment dust from baghouses; filter cartridges; and obsolete products/customer returns.

The waste minimization methods listed in Table 4 can be classified generally as source reduction, which can be achieved through material substitution, process or equipment modification, or better operating practices; or as recycling. An example of a source reduction method in the table is the use of countercurrent rinsing to reduce the volume of cleaning waste, while an example of recycling is the working of spilled product back into the process.

Table 4. Waste Minimization Methods for the Paint Manufacturing Industry

Waste Stream	Waste Minimization Methods
Equipment cleaning wastes (rinsewater, solvent and sludge)	Use mechanical wipers on mix tanks. Use high pressure wash systems. Install Teflon liners on mix tanks. Use foam/plastic pigs to clean lines. Reuse equipment cleaning wastes. Schedule production to minimize need for cleaning. Clean equipment immediately. Use countercurrent rinse methods. Use alternative cleaning agents. Increase spent rinse settling time.* Use de-emulsifiers on spent rinses.*
Spills and off spec paint	Increase use of automation. Use appropriate clean up methods. Recycle back into process. Implement better operating practices.
Leftover inorganic pigment in bags and packages	Use water soluble bags and liners. Use recyclable/lined/dedicated containers.
Air emissions, including pigment dust	Modify bulk storage tanks. Use paste pigments. Install dedicated baghouse systems.
Filter cartridges	Improve pigment dispersion. Use bag or metal mesh filters.
Obsolete products/customer returns	Blend into new products.

*These methods can only be viewed as waste minimization if they allow the continued use of spent cleaning solutions.

Better operating practices are procedural or institutional policies that result in a reduction of waste. They include:

- Waste stream segregation
- Personnel practices
  - Management initiatives
  - Employee training
  - Employee incentives
- Procedural measures
  - Documentation
  - Material handling and storage
  - Material tracking and inventory control
  - Scheduling
- Loss prevention practices
  - Spill prevention
  - Preventive maintenance
  - Emergency preparedness
- Accounting practices
  - Apportion waste management costs to departments that generate the waste

Better operating practices apply to all waste streams. In addition, specific better operating practices that apply to certain waste streams are identified in the appropriate sections that follow.

EQUIPMENT CLEANING WASTES

Equipment cleaning generates most of the waste associated with paint manufacturing. Following production of either solvent or water–based paints, considerable waste or "clingage" remains affixed to the sides of the preparation tanks. The three methods of tank cleaning used in the paint industry are solvent washing for solvent–based paint, caustic washing for either solvent or water–based paint, and water washing for water–based paint.

Equipment used for preparation of solvent–based paint is rinsed with solvent, which is then generally reused in the following ways:

- Collected and used in the next compatible batch of paint as part of the formulation.
- Collected and re–distilled either on or off–site.
- Collected and used with or without settling for equipment cleaning, until spent. When the solvent is finally spent, it is then drummed for disposal.

In 1985, a survey conducted by the National Paint & Coatings Association's Manufacturing Management Committee showed that over 82% of the respondents recycled all of their solvent waste either on-site or off-site. With current costs of disposal, onsite distillation of solvent can be economically justified for as little as eight gallons of solvent waste generated per day. Of all the solvent that is recycled, 75 percent is recovered with the remaining portion disposed of as sludge.

Caustic rinse is used for equipment cleaning of both solvent and water–based paints, but more often with water–based paints. Water rinsing is usually insufficient in removing paint that has dried in the mix tanks. Since solvent rinsing can usually remove solvent–based paint that has dried, the need for caustic is less.

There are two major types of caustic systems commonly used by the paint industry. In one type of system, caustic is maintained in a holding tank (usually heated) and is pumped into the tank to be cleaned. The caustic drains to a floor drain or sump from which it is returned to the holding tank. In the second type of system, a caustic solution is prepared in the tank to be cleaned, and the tank is soaked until it is clean. Most plants reuse the caustic solution until it loses most of its cleaning ability. At that time, the caustic is disposed of either as a solid waste or wastewater with or without neutralization.

Water wash of equipment used in the production of water–based paint is the source of considerable wastewater volume, which is usually handled as follows:

- Collected and used in the next compatible batch of paint as part of the formulation.
- Collected and used with or without treatment for cleaning until spent.
- Disposed with or without treatment as wastewater or as a solid waste in drums.

Sludges from settling tanks are drummed and disposed of as solid waste. Spent recycle rinsewater is drummed and disposed of as solid waste after the soluble content prohibits further use.

The percentage of solvent–base and water–base paints produced is the most important factor that affects the volume of process wastewater generated and discharged at paint plants. Due to their greater use of water–wash, plants producing 90 percent or more water–base paint discharge more wastewater than plants producing 90 percent or more solvent–base paint. Additional factors influencing the amount of wastewater produced include the pressure of the rinse water, spray head design, and the existence or absence of floor drains. Where no troughs or floor drains exist, equipment is often cleaned externally by hand with rags; when wastewater drains are present, there is a greater tendency to use hoses. Several plants have closed their floor drains to force the use of dry clean–up methods and discourage excessive water use.

Waste associated with equipment cleaning represents the largest source of waste in a paint facility. Methods that reduce the need or frequency of tank cleaning or allow for reuse of the cleaning solutions are the most effective. Waste minimization methods considered include:

Use of mechanical devices such as rubber wipers. In order to reduce the amount of paint left clinging to the walls of a mix tank, rubber wipers are used to scrape the sides of the tank. This operation requires manual labor and hence the percentage of waste reduction is a function of the operator. Since the benefits will be offset by increased labor, mechanization/automation should be considered. Many new mixers are available that are designed with automatic wall scrapers (Weismantel and Guggilam 1985). These mixers can be used with any cylindrical mix tank (flat or conical bottom).

Use of high pressure spray heads and limitingwash/rinse time. After scraping the tank walls, high pressure spray hoses can be used in place of regular hoses to clean water–based paint tanks. Based on studies (USEPA 1979), high pressure wash systems can reduce water use by 80 to 90 percent. In addition, high pressure sprays can remove partially dried–on paint so that the need for caustic is reduced. Tanks used for making solvent–based paints normally employ a built–in high pressure cleaning system. At Lilly, in High Point, N.C., a high pressure cleaning system was installed in several mix tanks. By continuously pumping a fixed amount of solvent into a tank until it was clean, the overall volume of solvent required for cleaning was reduced (Kohl, Moses, and Triplett 1984).

Use of Teflon lined tanks to reduce adhesion and improve drainage.* The reduced amount of "clingage" will make dry cleaning more attractive. This method is probably applicable only to small batch tanks amenable to manual cleaning.

Use of a plastic or foam "pig" to clean pipes. It was reported that much of the industry is currently using plastic or foam "pigs" (slugs) to clean paint from pipes. The "pig" is forced through the pipe from the mixing tank to the filling machine hopper. The "pig" pushes ahead paint left clinging to the walls of the pipe. This, in turn, increases yield and reduces the subsequent degree of pipe cleaning required. Inert gas is used to propel the "pig" and minimize drying of paint inside the pipe. The equipment (launcher and catcher) must be carefully designed so as to prevent spills, sprays, and potential injuries, and the piping runs must be free of obstructions so that the "pig" does not become stuck or lost in the system.

Better operating practices. At Desoto, in Greensboro, N.C., wash solvent from each solvent–based paint batch is separately collected and stored. When the same type of paint is going to be produced, waste solvent from the previous batch is used in place of virgin solvent. In 1981, Desoto produced 25,000 gallons of waste mineral spirits. In 1982, when the system was implemented, waste solvent production amounted to 400 gallons. This same technique is currently being applied to their latex paint production operation (Kohl, Moses and Triplett 1984).

In some cases, cleaning sludge can be recycled. One of the audited facilities discussed in the DHS report (Calif. DHS 1987) recycles the sludge from alkaline cleaning of their water-based paint mix tanks into a marketable product.

Other waste minimization measures based on good operating practices would be to schedule paint production for long runs or to cycle from light to dark colors so that the need for equipment cleaning would be reduced. For facilities using small portable mix tanks for water-based paints, immediate cleaning after use would reduce the amount of paint drying in the tank and hence reduce the need for caustic. Many times, dirty equipment is sent to a central cleaning operation where it waits until a given shift (usually night) to be cleaned. While tanks wait to be cleaned, the residual paint dries up, often necessitating the use of caustic solution for cleaning. By designing and operating the cleaning operation to handle any peak load continuously, all need for caustic should be eliminated or drastically reduced.

For plants employing CIP (clean–in–place) and recycle systems for wash/rinse operations, the inventory replacement frequency and waste volume can be minimized by using these following waste reduction methods:

A countercurrent rinsing sequence. For facilities that have additional storage space available, countercurrent rinsing can be employed. This technique uses recycled "dirty" solution to initially clean the tank. Following this step, recycled "clean" solution is used to rinse the "dirty" solution from the tank. Since the level of contamination builds up more slowly in the recycled "clean" solution than with a simple reuse system, solution life is greatly increased. Countercurrent rinsing is more common with CIP systems, but can be used with all systems.

Alternative cleaning agent. Many facilities use caustic to clean their mixing equipment. When the build-up of solids and dissolved organics reaches a given concentration, the cleaning efficiency decreases and the solution must be replaced. As reported by one of the audited facilities, substituting a proprietary alkaline cleaning solution for their caustic solution cut the solution replacement frequency in half and thereby reduced the volume of cleaning solution requiring disposal.

**Registered trademark of E.I. Du Pont de Nemours & Co.*

Sludge dewatering by filtration or centrifugation. The above three methods are useful in reducing the amount of waste entering the environment provided they allow the continued use of the cleaning solution. Dewatering only to reduce sludge disposal volumes should not be viewed as waste minimization.

Provision for adequate solid settling time in spent rinse solution.

Use of de–emulsifiers in rinse water to promote emulsion breakdown and organic phase separation.

OFF-SPECIFICATION PAINT

Most off–specification paint is produced by small shops that deal in specialty paints. Since these paints cost more to produce, and therefore sell at a premium price, most off–spec paint is reworked into a salable product. Since elimination of off–spec paint production has built–in economic incentives, the following techniques are widely used:

Increased automation.

Better operating practices. Unless the sludge from wet cleanup can be recycled into a marketable product, the use of dry cleanup methods should be maximized wherever possible. By closing floor drains and discouraging employees from routinely (i.e. needlessly) washing down areas, some facilities have been able to achieve a large decrease in wastewater volume (USEPA 1979). Other effective ways to reduce water use include employing volume-limiting hose nozzles, using recycled water for cleanups, and actively involved supervision.

BAGS AND PACKAGES

Inorganic pigments, which may contain heavy metals and therefore be classified as hazardous, are usually shipped in 50 pound bags. After emptying the bag, an ounce or two of pigment usually remains inside. Empty containers of liquid raw materials that constitute hazardous waste (e.g. solvents and resins) are typically cleaned or recycled to the original raw material manufacturer or to a local drum recycler. Empty liquid containers are excluded from the following discussion. The following waste reduction techniques for bags and packages were noted:

Use of water soluble bags for toxic pigments and compounds used in water–based paints. When empty, the bags could be dissolved or mixed in with the paint. Such a method is commonly used for handling mercury compounds and other paint fungicides. This method could not be used, however, when producing high quality, smooth finish paint since the presence of this material could affect the paint's film forming property or could increase the load on the filters which would increase filter waste.

Use of rinseable/recyclable drums with plastic liners instead of paper bags.

Better operating practices. Through industry contacts, it was established that the most effective way of reducing hazardous waste associated with bags and packages (or any other waste stream) was to segregate the hazardous materials from the non–hazardous materials. As an example, empty packages that contained hazardous materials should be placed into plastic bags (so as to reduce or eliminate dusting leading to non–hazardous material contamination) and should be stored in a special container to await collection.

AIR EMISSIONS

The two major types of air emissions that occur in the paint manufacturing process are volatile organic compounds and pigment dusts. Volatile organics may be emitted from the bulk storage of resins and solvents and from their use in open processing equipment such as mix tanks. Since most existing equipment is of open design, reducing or controlling organic emissions from process equipment could require substantial expenditures in retrofit costs. Additional work on control methods appears to be warranted in this area, and as a result, the following measures only address bulk storage and pigment handling.

Control bulk storage air emissions. Many methods are available for reducing the amount of emissions resulting from fixed roof storage tanks. Some of these methods include use of conservation vents, conversion to floating roof, use of nitrogen blanketing to suppress emissions and reduce material oxidation, use of refrigerated condensers, use of lean-oil or carbon absorbers, or use of vapor compressors. When dealing with volatile materials, employment of one or more of these methods can result in cost savings to the facility by reducing raw material losses.

Some of the dusts generated during the handling, grinding, and mixing of pigments can be hazardous. Therefore, dust collection equipment (hoods, exhaust fans, and baghouses) are provided to minimize a worker's exposure to localized dusting and to filter ventilation air exhaust. The waste reduction methods considered consist of:

Use of pigments in paste form instead of dry powders. Pigments in paste form are dry pigments that have been wetted or mixed with resins. Since these pigments are wet, less dust or no dust is generated when the package is opened. In addition, most pigments in paste form are supplied in drums (which can be recycled) and therefore would eliminate the waste due to empty bags. While this method would increase the amount of pigment handling occurring at the supplier's facility, it can be argued that the overall number of handling/transfer points for dry powder will be greatly reduced along with the probability of spills and dust generation.

Dedicated baghouse system for pigment loading area. At Daly–Herring Co., in Kinston, N.C., (while Daly–Herring is engaged in the formulation of pesticides and not paints, there are many material handling problems common to both industries) dust streams from several different production areas were handled by a single baghouse. Since all of the streams were mixed, none of the waste could be recycled to the process that generated them. By installing separate dedicated baghouses for each production line, all of the collected pesticide dust could be recycled (Huisingh and Martin 1985). While this example is not intended to imply that most of the dust generated by the paint industry could be recycled, it does show the overall importance of keeping waste streams segregated.

SPILLS

Spills are due to accidental or inadvertent discharges usually occurring during transfer operations or equipment failures (leaks). Spilled paint and the resulting clean up wastes are usually discharged to the wastewater treatment system or are directly drummed for disposal. If the plant has floor drains, large quantities of water may be used to clean up water–based paint spills. Dry cleaning methods are employed for cleaning of solvent–containing spills or for water–based spills where floor drains are not available. Waste reduction methods similar to those for off-spec paint include:

Increased automation.

Better operating practices. Unless the sludge from wet cleanup can be recycled into a marketable product, the use of dry cleanup methods should be maximized wherever possible. By closing floor drains and discouraging employees from routinely (i.e. needlessly) washing down areas, some facilities have been able to achieve a large decrease in wastewater volume (USEPA 1979). Other effective ways to reduce water use include employing volume-limiting hose nozzles, using recycled water for cleanups, and actively involved supervision.

FILTER CARTRIDGES

Spent filter cartridges are produced during the paint loading operation. These cartridges are designed to remove undispersed pigment from the paint during loading and are saturated with paint when removed. Hence, waste minimization and economy both call for as small a cartridge as possible so as to reduce the amount of paint lost and the capital spent for the filters. If frequent filter plugging is a problem, then it should be first addressed from the standpoint of improving pigment dispersion, and not from the standpoint of increasing filter area.

Viable alternatives to cartridge filters include bag filters and metal mesh filters. Metal mesh filters are available in very fine micron sizes and they can be cleaned and reused. Since it is very important to minimize all wastes, the issue of mesh filter cleaning waste reuse or recyling would need to be addressed before switching to these filters.

OBSOLETE PRODUCTS/CUSTOMER RETURNS

Obsolete products and customer returns can be blended into new batches of paint. Obsolete products result from changes in customer demand, new superior products, and expired shelf life. Marketing policies, such as discounting older paints, can reduce the amount of obsolete products requiring disposal.

References

Huisingh, D. and L. Martin. 1985. *Proven Profit from Pollution Prevention.* Conference draft. The Institute for Local Self-Reliance, Washington, D.C.

Kohl, J., P. Moses, and B. Triplett. 1984. *Managing and Recycling Solvents. North Carolina Practices, Facilities, and Regulations.* Raleigh, N.C.; North Carolina State University.

USEPA 1979. U. S. Environmental Protection Agency, Office of Water and Waste Management. Development document for proposed effluent limitation guidelines, new source performance standards, and pretreatment standards for the paint formulating point source category. EPA–440–1–79–049b. Washington, D.C.: U.S. Environmental Protection Agency.

Weismantel, G., and S. Guggilam. 1984. Mixing and size reduction (A chemical engineering special advertising section). *Chem. Eng.* 92(13): 71–109.

SECTION 4
GUIDELINES FOR USING THE WASTE MINIMIZATION ASSESSMENT WORKSHEETS

Waste minimization assessments were conducted at several paint manufacturing plants in the Los Angeles area. The assessments were used to develop the waste minimization questionnaire and worksheets that are provided in the following section.

A comprehensive waste minimization assessment includes a planning and organizational step, an assessment step that includes gathering background data and information, a feasibility study on specific waste minimization options, and an implementation phase.

Conducting Your Own Assessment

The worksheets provided in this section are intended to assist paint manufacturers in systematically evaluating waste generating processes and in identifying waste minimization opportunities. These worksheets include only the assessment phase of the procedure described in the Waste Minimization Opportunity Assessment Manual. For a full description of waste minimization assessment procedures, refer to the EPA Manual.

Table 5 lists the worksheets that are provided in this section.

Table 5. List of Waste Minimization Assessment Worksheets

Number	Title	Description
1.	Waste Sources	Typical wastes generated at paint manufacturing plants.
2A.	Waste Minimization: Material Handling	Questionnaire on general handling techniques for raw material handling.
2B.	Waste Minimization: Material Handling	Questionnaire on procedures used for bulk liquid handling.
2C.	Waste Minimization: Material Handling	Questionnaire on procedures used for handling drums, containers and packages.
3.	Option Generation: Material Handling	Waste minimization options for material handling operations.
4.	Waste Minimization: Material Substitution/ Primary Dispersion Techniques	Questionnaire on material substitution and primary dispersion operations.
5.	Option Generation: Material Substitution/ Primary Dispersion Techniques	Waste minimization options for material substitution and modification of the primary dispersion operations.
6.	Waste Minimization: Process Modification (Let-Down)	Questionnaire on let-down procedures.
7.	Option Generation: Let-Down Techniques	Waste minimization opportunities for let-down techniques.
8.	Waste Minimization: Process Modification (Filtering and Filling)	Questionnaire on filtering, filling, and on-site tank cleaning procedures.
9.	Option Generation: Filtering and Filling	Filtering and filling waste minimization options.
10.	Waste Minimization: Good Operating Practices	Questionnaire on use of good operating practices.
11.	Option Generation: Good Operating Practices	Waste minimization options for good operating practices.
12.	Waste Minimization: Reuse and Recovery	Questionnaire on opportunities for reuse and recovery of wastes.

Firm _____ Site _____ Date _____	Waste Minimization Assessment Proj. No. _____	Prepared By _____ Checked By _____ Sheet __ of __ Page __ of __

WORKSHEET 1

WASTE SOURCES

Waste Source: Material Handling	Significance at Plant		
	Low	Medium	High
Off-spec materials			
Obsolete raw materials			
Obsolete products			
Spills & leaks (liquids)			
Spills (powders)			
Empty container cleaning			
Container disposal (metal)			
Container disposal (paper)			
Pipeline/tank drainage			
Laboratory wastes			
Evaporative losses			
Other			
Waste Source: Process Operations			
Mill cleaning			
Portable tank cleaning			
Container cleaning			
Stationary tank cleaning			
Mixer cleaning			
Filter equipment cleaning			
Spent filter elements			
Filling equipment cleaning			
Baghouse fines			
Other			

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____		Checked By _____
Date _____	Proj. No. _____	Sheet __ of __ Page __ of __

WORKSHEET
2A

WASTE MINIMIZATION: Material Handling

A. GENERAL HANDLING TECHNIQUES

Are all raw materials tested for quality before being accepted from suppliers? ❑ yes ❑ no

Describe safeguards to prevent the use of materials that may generate off-spec product: _____

_____

_____

_____

_____

Is obsolete raw material returned to the supplier? ❑ yes ❑ no

Is inventory used in first-in first-out order? ❑ yes ❑ no

Is the inventory system computerized? ❑ yes ❑ no

Does the current inventory control system adequately prevent waste generation? ❑ yes ❑ no

What information does the system track? _____

_____

_____

_____

_____

_____

Is there a formal personnel training program on raw material handling, spill prevention, proper storage techniques, and waste handling procedures? ❑ yes ❑ no

Does the program include information on the safe handling of the types of drums, containers and packages received? ❑ yes ❑ no

How often is training given and by whom? _____

_____

_____

_____

Firm _____ Site _____ Date _____	Waste Minimization Assessment Proj. No. _____	Prepared By _____ Checked By _____ Sheet __ of __ Page __ of __

WORKSHEET
2B

WASTE MINIMIZATION: Material Handling

B. BULK LIQUIDS HANDLING

What safeguards are in place to prevent spills and avoid ground contamination during the filling of storage tanks?

High level shutdown/alarms ❑ Secondary containment ❑
Flow totalizers with cutoff ❑ Other ❑

Describe the system: _____

Are air emissions from solvent storage tanks controlled by means of:

Conservation vents	❑ yes	❑ no
Nitrogen blanketing	❑ yes	❑ no
Absorber/Condenser	❑ yes	❑ no
Other vapor loss control system	❑ yes	❑ no

Describe the system: _____

Are all storage tanks routinely monitored for leaks? ❑ yes ❑ no

Describe procedure and monitoring frequency for above-ground/vaulted tanks: _____

Underground tanks: _____

How are the liquids in these tanks dispensed to the users? (i.e., in small containers or hard piped.) _____

What measures are employed to prevent the spillage of liquids being dispensed? _____

When a spill of liquid occurs in the facility, what cleanup methods are employed (e.g., wet or dry)? Also discuss the way in which the resulting wastes are handled: _____

Would different cleaning methods allow for direct reuse or recycling of the waste? (explain): _____

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____		Checked By _____
Date _____	Proj. No. _____	Sheet __ of __ Page __ of __

WORKSHEET
2C

WASTE MINIMIZATION: Material Handling

C. DRUMS, CONTAINERS, AND PACKAGES

Are drums, packages, and containers inspected for damage before being accepted? ❑ yes ❑ no
Are employees trained in ways to safely handle the types of drums & packages received? ❑ yes ❑ no
Are they properly trained in handling of spilled raw materials? ❑ yes ❑ no
Are stored items protected from damage, contamination, or exposure to rain, snow, sun & heat? ❑ yes ❑ no

Describe handling procedures for damaged items: _____

❑ yes ❑ no

Does the layout of the facility result in heavy traffic through the raw material storage area? (Heavy traffic increases the potential for contaminating raw materials with dirt or dust and for causing spilled materials to become dispersed throughout the facility.) ❑ yes ❑ no
Can traffic through the storage area be reduced?

To reduce the generation of empty bags & packages, dust from dry material handling and liquid wastes due to cleaning of empty raw material drums and/or customer returns, has the facility attempted to:

- Use pigments in slurry/paste form? ❑ yes ❑ no
- Purchase hazardous materials in preweighed containers to avoid the need for weighing? ❑ yes ❑ no
- Purchase preweighed hazardous materials in water or solvent soluble bags? ❑ yes ❑ no
- Use reuseable/recyclable drums with liners instead of paper bags? ❑ yes ❑ no
- Use larger containers or bulk delivery systems that can be returned to supplier for cleaning? ❑ yes ❑ no
- Dedicate baghouse systems in the pigment loading area so as to segregate hazardous from non-hazardous dusts? ❑ yes ❑ no
- Reformulate the cleaning waste into a product? ❑ yes ❑ no

Discuss the results of these attempts: _____

Are all empty bags, packages, and containers that contained hazardous materials segregated from those that contained non-hazardous wastes? ❑ yes ❑ no

Describe method currently used to dispose of this waste: _____

Firm _____	**Waste Minimization Assessment**	Prepared By _____
Site _____	Proc. Unit/Oper. _____	Checked By _____
Date _____	Proj. No. _____	Sheet __ of __ Page __ of __

WORKSHEET
3

OPTION GENERATION: Material Handling

Meeting Format (e.g., brainstorming, nominal group technique) _____

Meeting Coordinator _____

Meeting Participants _____

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
A. General Handling Techniques		
Quality Control Check		
Return Obsolete Material To Supplier		
Minimize Inventory		
Computerize Inventory		
Formal Training		
B. Bulk Liquids Handling		
High Level Shutdown/Alarm		
Flow Totalizers with Cutoff		
Secondary Containment		
Air Emission Control		
Leak Monitoring		
Spilled Material Reuse		
Cleanup Methods to Promote Recycling		
C. Drums, Containers, and Packages		
Raw Material Inspection		
Proper Storage/Handling		
Slurry/Paste Pigments		
Preweighed Containers		
Soluble Bags		
Reusable Drums		
Bulk Delivery		
Dedicated Baghouses		
Waste Segregation		
Reformulate Cleaning Waste		

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____		Checked By _____
Date _____	Proj. No. _____	Sheet __ of __ Page __ of __

WORKSHEET
4

WASTE MINIMIZATION: Material Substitution Primary Dispersion Techniques

A. MATERIAL SUBSTITUTION

Do any of the paints or coatings produced contain hazardous materials (i.e., chlorinated solvents, lead or chrome pigments, mercury, etc.)? ❑ yes ❑ no

If yes, has material substitution been tried? ❑ yes ❑ no

Discuss the results: _____

B. PRIMARY DISPERSION (skip this section if mills not used)

Are separate containers used for feeding and receiving materials passed through the mill?	❑ yes	❑ no
Are multiple passes of the material through the mill often required?	❑ yes	❑ no
Can the number of containers used (requiring cleaning) be reduced by continuously recirculating the material through the mill instead of using multiple passes?	❑ yes	❑ no
Would the purchase of a more efficient mill eliminate the need for multiple passes?	❑ yes	❑ no
Is dispersed material used immediately for let-down?	❑ yes	❑ no
If sent to storage, does the material often require redispersion?	❑ yes	❑ no
Would reducing the amount of material sent to intermediate storage reduce the use of the mill and the subsequent need for cleaning?	❑ yes	❑ no

Discuss: _____

Is solvent used for cleaning the mills?	❑ yes	❑ no
Can the cleaning waste be used as part of the formulation during let-down?	❑ yes	❑ no
As part of another formulation or for other cleaning activities?	❑ yes	❑ no
Can the type of cleaning agent be standardized so as to promote reuse or recycling?	❑ yes	❑ no

Discuss: _____

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____	Proc. Unit/Oper. _____	Checked By _____
Date _____	Proj. No. _____	Sheet __ of __ Page __ of __

WORKSHEET
5

OPTION GENERATION: Material Substitution Primary Dispersion Techniques

Meeting format (e.g., brainstorming, nominal group technique) _____

Meeting Coordinator _____

Meeting Participants _____

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
A. Substitution/Reformulation Techniques		
Pigment Substitution		
Solvent Substitution		
Product Reformulation		
Other Raw Material Substitution		
B. Primary Dispersion Techniques		
Recirculation Through Mill		
Install Efficient Mills		
Improve Production Planning		
Dedicate Mills		
Clean with Part of Batch		
Reuse Rinse Solvent		
Standardize Cleaning Solvent		
Mechanical Cleaning		
Waste Segregation		

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____		Checked By _____
Date _____	Proj. No. _____	Sheet ___ of ___ Page ___ of ___

WORKSHEET
6

WASTE MINIMIZATION: Process Modification

LET-DOWN TANKS

Is the piping to and from the let-down tanks routinely flushed with water or solvent? ❑ yes ❑ no
Is the piping "pigged" before flushing? ❑ yes ❑ no

Describe how waste from flushing is handled: _____

Describe the cleaning sequence (i.e., manually scraped, washed with a high-pressure spray system using caustic, then solvent rinsed) used for cleaning portable let-down tanks: _____

Describe the cleaning sequence used for cleaning fixed let-down tanks: _____

Describe the cleaning sequence used for cleaning the mixing units: _____

How are cleaning wastes handled and disposed of? _____

Much more drastic cleaning measures are usually required when the paint is allowed to dry inside the tank. Are all of the tanks cleaned promptly after use? ❑ yes ❑ no
Are any precautions taken during this time to prevent the paint from drying? ❑ yes ❑ no
Describe: _____

Are there established procedures for communications between cleaning & production crew? ❑ yes ❑ no
For situations where the paint does dry in the tank, is your spray cleaning system effective? ❑ yes ❑ no
Has the use of new nozzle heads or higher pump pressures been attempted? ❑ yes ❑ no
If a high-pressure spray system is not used for cleaning tanks, are there plans to install one? ❑ yes ❑ no
If caustic is used, have alternative commercial cleaning solutions been tried? ❑ yes ❑ no
Results: _____

Can batches be sequenced from light-to-dark to reduce cleaning needs? ❑ yes ❑ no
Has the facility investigated the effect of reduced cleaning on product quality? ❑ yes ❑ no
Was the testing performed on a lab scale or in production? ❑ yes ❑ no
Results: _____

Firm _____ Site _____ Date _____	**Waste Minimization Assessment** Proc. Unit/Oper. _____ Proj. No. _____	Prepared By _____ Checked By _____ Sheet __ of __ Page __ of __

WORKSHEET **7**

OPTION GENERATION: Let-Down Techniques

Meeting format (e.g., brainstorming, nominal group technique) _____

Meeting Coordinator _____

Meeting Participants _____

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
Let-Down Techniques		
"Pigging" Pipelines		
Mechanical Cleaning		
Clean Promptly		
Proper Communications		
Prevent Paint Drying		
High Pressure Spray Cleaning		
Use of Efficient Nozzles		
Replace Caustic Solution		
Light-to-Dark Sequence		
Avoid Unnecessary Cleaning		
Dedicate Tanks		
Standardize Cleaning Solvent		
Reuse/Rework Solvent Waste		
Waste Segregation		
Ensure Proper Batching		
Minimize Evaporative Loss		

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____		Checked By _____
Date _____	Proj. No. _____	Sheet __ of __ Page __ of __

WORKSHEET
8

WASTE MINIMIZATION: Process Modification

FILTERING & FILLING

Are any of the filter units dedicated to a particular product line? ☐ yes ☐ no

Would increased dedication reduce the need for filter replacement or cleaning? ☐ yes ☐ no

Has the facility attempted to replace disposable cartridge filters with reusable filters such as bags or metal mesh? ☐ yes ☐ no

What type of reusable filter was tried and what were the results: _____

How are the wastes from spent filter cartridges or reusable filter cleaning handled? _____

Are any of the filling units dedicated to a particular product line? ☐ yes ☐ no

Would increased dedication reduce the need for cleaning? ☐ yes ☐ no

Describe the filling unit cleaning procedures and how cleaning wastes are handled. _____

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____	Proc. Unit/Oper. _____	Checked By _____
Date _____	Proj. No. _____	Sheet __ of __ Page __ of __

WORKSHEET
9

OPTION GENERATION: Filtering & Filling

Meeting format (e.g., brainstorming, nominal group technique) _____

Meeting Coordinator _____

Meeting Participants _____

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
Filtering & Filling Techniques		
Dedicate Filter Units		
Use Wire Screen Filters		
Use Bags, Not Cartridges		
Reuse Filter Bags		
Dedicate Filling Units		
Light-to-Dark Sequence		

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____		Checked By _____
Date _____	Proj. No. _____	Sheet __ of __ Page __ of __

WORKSHEET
10

WASTE MINIMIZATION: Good Operating Practices

A. PRODUCTION SCHEDULING TECHNIQUES

Is the production schedule varied to decrease waste generation? (For example, do you attempt to increase size of production runs and minimize cleaning by accumulating orders or production for inventory?) ❑ yes ❑ no

Describe: _____

Does the production include light-to-dark manufacturing sequence? ❑ yes ❑ no

If yes, indicate results: _____

Are there any other attempts at eliminating cleanup steps between subsequent batches? ❑ yes ❑ no

If yes, results: _____

B. AVOIDING OFF-SPEC PRODUCTS

Is the batch formulation attempted in the lab before large scale production? ❑ yes ❑ no

C. GOOD OPERATING PRACTICES

Are plant material balances routinely performed?	❑ yes	❑ no
Are they performed for each material of concern (e.g. solvent) separately?	❑ yes	❑ no
Are records kept of individual wastes with their sources of origin and eventual disposal? (This can aid in pinpointing large waste streams and focus reuse efforts.)	❑ yes	❑ no
Are the operators provided with detailed operating manuals or instruction sets?	❑ yes	❑ no
Are all operator job functions well defined?	❑ yes	❑ no
Are regularly scheduled training programs offered to operators?	❑ yes	❑ no
Are there employee incentive programs related to waste minimization?	❑ yes	❑ no
Does the facility have an established waste minimization program in place?	❑ yes	❑ no
If yes, is a specific person assigned to oversee the success of the program?	❑ yes	❑ no

Discuss goals of the program and results: _____

Has a waste minimization assessment been performed at the facility in the past? ❑ yes ❑ no

If yes, discuss: _____

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____	Proc. Unit/Oper. _____	Checked By _____
Date _____	Proj. No. _____	Sheet __ of __ Page __ of __

WORKSHEET
11

OPTION GENERATION: Good Operating Practices

Meeting format (e.g., brainstorming, nominal group technique) _____

Meeting Coordinator _____

Meeting Participants _____

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
A. Production Scheduling Techniques		
Increase Size of Production Run		
Light-to-Dark Sequence		
Avoid Unnecessary Cleaning		
B. Avoiding Off-Spec Products		
Test Batch Formulation in Lab		
C. Good Operating Practices		
Perform Material Balances		
Keep Records of Waste Sources & Disposition		
Waste/Materials Documentation		
Provide Operating Manuals/Instructions		
Employee Training		
Increased Supervision		
Provide Employee Incentives		
Encourage Dry Cleanup		
Increase Plant Sanitation		
Establish Waste Minimization Policy		
Set Goals for Source Reduction		
Set Goals for Recycling		
Conduct Annual Assessments		

Firm _____	Waste Minimization Assessment	Prepared By _____
Site _____		Checked By _____
Date _____	Proj. No. _____	Sheet __ of __ Page __ of __

WORKSHEET
12

WASTE MINIMIZATION: Reuse and Recovery

A. SEGREGATION

Segregation of wastes reduces the amount of unknown material in waste and improves prospects for reuse & recovery.

Are different solvent wastes due to equipment clean-up segregated?	❑ yes	❑ no
Are aqueous wastes from equipment clean-up segregated from solvent wastes?	❑ yes	❑ no
Are spent alkaline solutions segregated from the rinse water streams?	❑ yes	❑ no

If no, explain: _____

B. ON-SITE RECOVERY

On-site recovery of solvents by distillation is economically feasible for as little as 8 gallons of solvent waste per day.

Has on-site distillation of the spent solvent ever been attempted?	❑ yes	❑ no
If yes, is distillation still being performed?	❑ yes	❑ no

If no, explain: _____

C. CONSOLIDATION/REUSE

Are many different solvents are used for cleaning?	❑ yes	❑ no
If too many small-volume solvent waste streams are generated to justify on-site distillation, can the solvent used for equipment cleaning be standardized?	❑ yes	❑ no
Is spent cleaning solvent reused?	❑ yes	❑ no
Are there any attempts at making the rinse solvent part of a batch formulation (rework)?	❑ yes	❑ no
Are any attempts made to blend various waste streams to produce marketable products?	❑ yes	❑ no
Are spills collected and reworked?	❑ yes	❑ no

Describe which measures were successful and for which types of paint: _____

	❑ yes	❑ no
Is your solvent waste segregated from other wastes?	❑ yes	❑ no
Has off-site reuse of wastes through Waste Exchange services been considered?	❑ yes	❑ no

Or reuse through commercial brokerage firms?

If yes, results: _____

APPENDIX A

CASE STUDIES OF PAINT MANUFACTURING PLANTS

In 1986 the California Department of Health Services commissioned a waste minimization study (DHS 1987) of two paint manufacturing firms, called Plants A and B in this guide. The results of the two waste assessments were used to prepare waste minimization assessment worksheets to be completed by other paint manufacturers in a self-audit process. The worksheets were sent to a third paint manufacturer, to test their effectiveness in guiding an assessment.

The paint manufacturing plants were chosen for their willingness to participate in the study, their applicability to the study's objectives, and the potential usefulness of the resulting data to the industry as a whole. Plant A produces water-based architectural coatings and Plant B produces solvent-based industrial coatings. The waste minimization assessments were concerned with waste generated within the plant boundaries and not with waste derived from paint application or disposal of painted parts or stripped paint.

This Appendix section presents the results of the assessments of Plants A and B and potentially useful waste minimization options identified through the assessments. Also included are the practices already in use at the plant that have successfully reduced waste generation from past levels.

The waste minimization assessments were conducted according to the description of such assessments found in the "Introduction: Overview of Waste Minimization," in this guide. The steps involved in the assessments were (see also Figure 1):

- Planning and organization
- Assessment phase
- Feasibility analysis phase

The fourth phase, Implementation, was not a part of these assessments since they were conducted by an outside consulting firm. It was left to the paint manufacturers themselves to take steps to implement the waste minimization opyions that passed the feasibility analysis.

PLANT A WASTE MINIMIZATION ASSESSMENT

Planning and Organization

Planning and organization of the assessment was done by the consulting firm with the assistance of personnel from the paint manufacturing firm. Initial contact was made with the paint manufacturer's plant operations manager, a high level manager who could provide the company's commitment to cooperate in the assessment and provide all the necessary facility and process information. The goal of this joint effort was to conduct a comprehensive waste minimization assessment for the plant. Under different circumstances, in a company with its own ongoing waste minimization program, goals could be set to target a specific amount or type of waste to be reduced; or to conduct a waste minimization assessment each year; or other goal. The waste assessment task force in the case of Plant A consisted of the consultants working together with the plant manager. This task force also functioned as the assessment team.

Assessment Phase: Process and Facility Data

Initial discussions by telephone between the consultants and the plant manager were used to request process and facility information prior to a site visit. These discussions also served to identify particular waste streams of concern to plant managers -- in particular, the disposal of cartridge filters.

At the site visit, the plant operations manager and consultants met to review the facility's operations and its potential target waste streams. The manager conducted a facility tour and introduced the consultants to process managers and workers involved in materials and waste handling. Some of these people were interviewed to obtain information about specific procedures used at the plant.

FACILITY DESCRIPTION

Plant A produces a wide variety of architectural coatings: 76 lines of paint products and eight lines of aerosol spray paints for distribution through retail outlets, and 55 lines of aerosol and specialty paints for sale through distributors. About 80 percent of the paints produced at this facility are water-based and the remainder are solvent-based. The water-based coatings are latexes and the solvent-based coatings are mostly alkyd resins dissolved in solvents. Figure A-1 presents the annual production rates of paints since 1982. Most of the paints produced are for use by the general public.

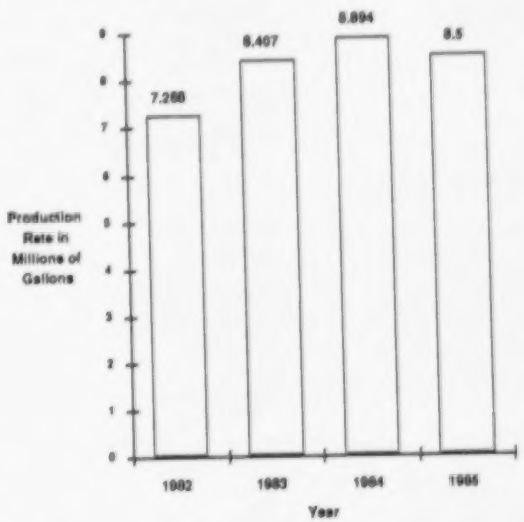


Fig. A-1. Annual Production Rates of Paints at Plant A since 1982

RAW MATERIALS MANAGEMENT

The raw materials used at Plant A include resin solutions, emulsions, solvents, pigments, bactericides, fungicides, and extenders. Some defoamers and surfactants are also added to the water-based batches. Table A-1 lists the principal raw materials used by the plant in 1985.

The solvents used at this facility include aliphatics, aromatics, ketones, or glycol ethers. Glycols such as diethylene glycol, propylene glycol, or Texanol are added to the water-based formulations to increase the paint drying time and to act as an anti-freeze. The solvents are

either delivered and stored in drums or delivered in bulk and held in the above-ground diked storage tanks.

The pigments are delivered in bags when used in powder form, and in drums or in bulk when used in slurried form. The use of slurried pigments is predominant in water-based formulations. Some solvent-based formulations use pigments in paste form, which are purchased in five gallon containers.

A complete inventory check is done four times a year, though limited inventory checks are done on a daily basis. Plant A is planning to convert from a manual to a computerized inventory system.

Table A-1. Raw Materials Used at Plant A

Description	Material
Solvents	Aliphatics
	Aromatics
	Ketones
	Alcohols
	Diethylene glycol
	Propylene glycol
Resins	Acrylics
	Vinyl-acrylics
	Alkyds
Pigments	Titanium dioxide
	Organic pigments
	Red oxide
	Yellow oxide
	Other inorganic pigments
Extenders	Calcium carbonate
	Clay
	Talc
	Silicates
Miscellaneous Additives	Bactericides and fungicides
	Surfactants and defoamers
	Viscosity modifiers
	Ammonia
	Others

PROCESS DESCRIPTION

The production of paints at Plant A is shown in block flow diagrams in Figures A-2 through A-7. The description is general enough to apply to the production of both solvent- and water-based paints in most cases.

The first step in paint production is the dispersion of the pigments (see Figure A-2). The pigments in emulsion or slurry form, along with the solvents, resins, and additives are added directly to a mill in the primary dispersion step. The dispersed material from the mill is then pumped directly to the let-down tanks. In less than five percent of the cases, the pigments (in emulsion, slurry, or dry form) are added to other raw materials in a portable tank or a small container. The contents of the tank or container are then dispersed in a sand mill, ball mill, or high-speed mill and either collected in another portable tank or directly added to the let-down tank. In all cases, the portable tanks or containers are reused several times without any cleaning but are ultimately sent for cleaning.

The dispersion mills are dedicated to a particular type The dispersion mills are dedicated to a particular type of product to the fullest extent possible. The dedicated mills are not cleaned. The non-dedicated mills are purged with solvent or water at the end of the dispersion process and the wash material is mixed with the dispersed product in the let-down step.

In the let-down step (see Figures A-4 and A-5), the dispersed pigments from milling operation are mixed in portable or stationary tanks with additional diluents, resins, and additives. The tanks have capacity varying from 50 to 10,000 gallons. The additives constitute bactericides, fungicides, surfactants, defoamers, or extenders. The bactericides and fungicides used for water-based batches are mercury-based whereas non-mercurials are used for solvent-based batches. Solvents such as diethylene glycol or propylene glycol are added to water-based paints to extend the drying time and act as an anti-freeze in cold climates.

The stationary tanks have a capacity greater than 400 gallons while the portable tanks have a 50- to 400-gallon capacity. About 25 percent of the total number of batches are let down using portable tanks, which accounts for less than 10 percent of the total paint volume produced at Plant A. The mixing in the tanks is performed using turbine mixers. When the properties of the batch reach the required standards, the mixing is stopped. The tank contents are then pumped through bag filters to the filling unit, which can fill five gallon, one gallon, 1/4 gallon, or 1/2 pint cans.

WASTE DESCRIPTION

The principal waste streams generated by Plant A include the following:

- Equipment cleaning wastes
- Obsolete stock

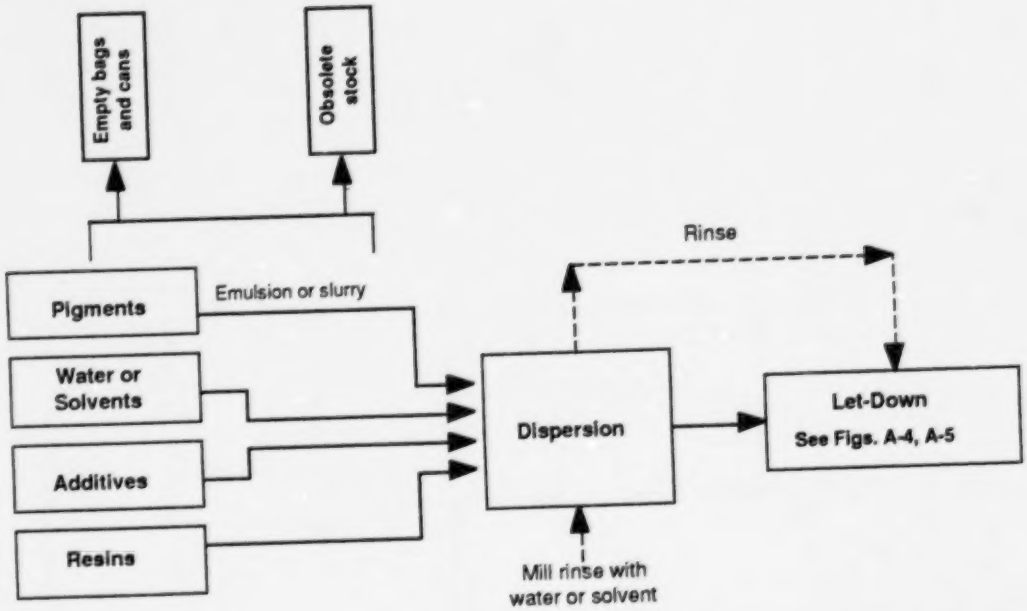


Figure A-2. Dispersion and Let-Down Steps - Prevalent Route

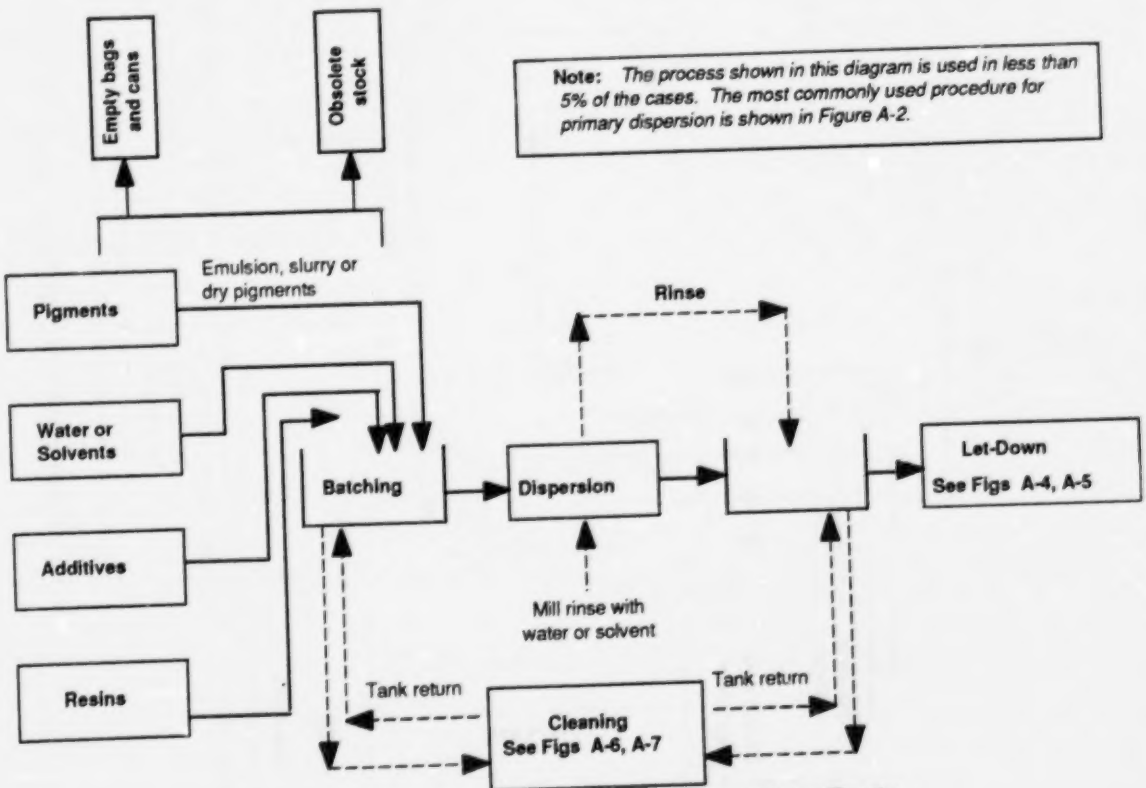
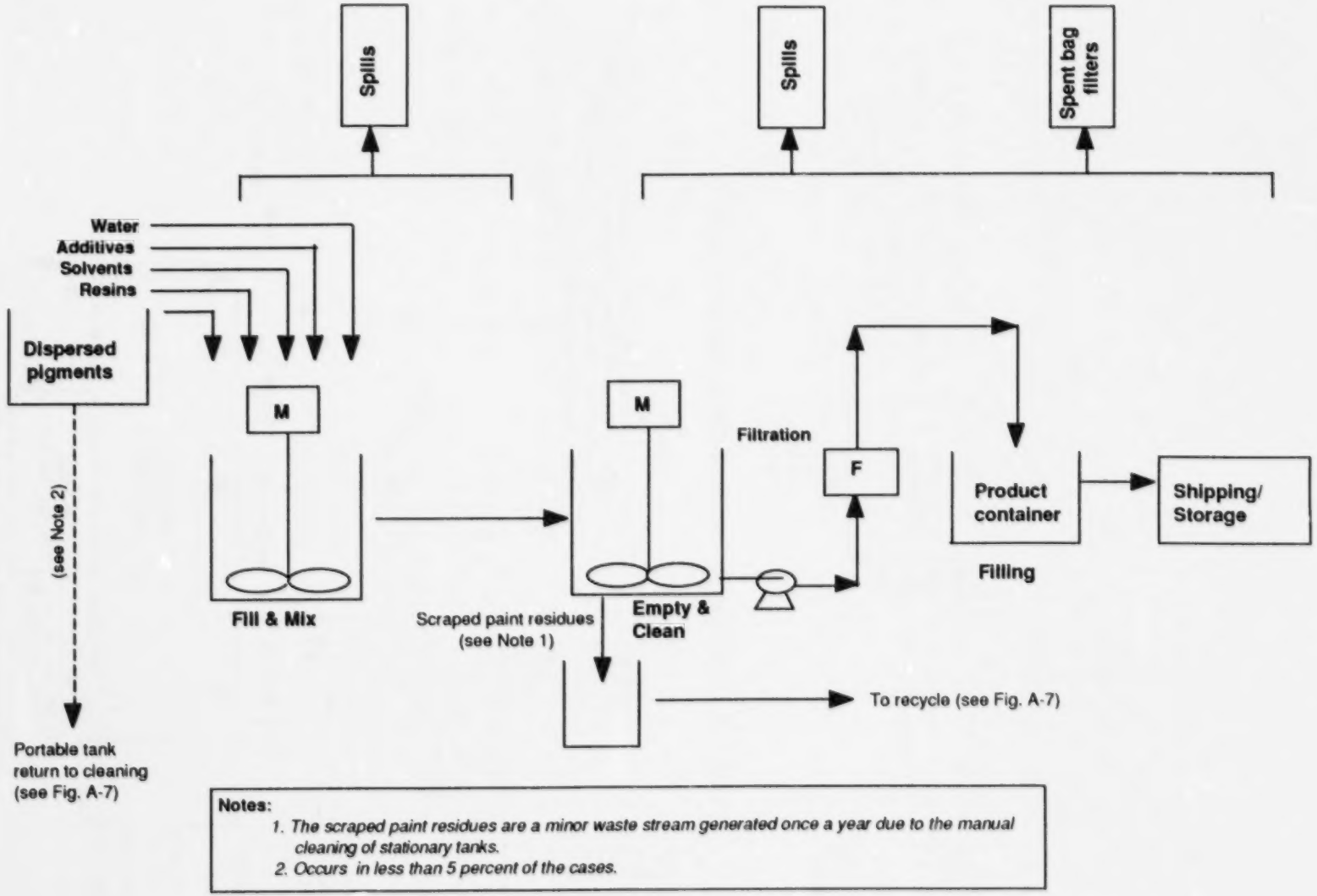


Figure A-3. Dispersion and Let-Down Steps - Minor Route



Notes:

1. *The scraped paint residues are a minor waste stream generated once a year due to the manual cleaning of stationary tanks.*
2. *Occurs in less than 5 percent of the cases.*

Figure A-4. Let Down Operation for Portable Tanks at Plant A.

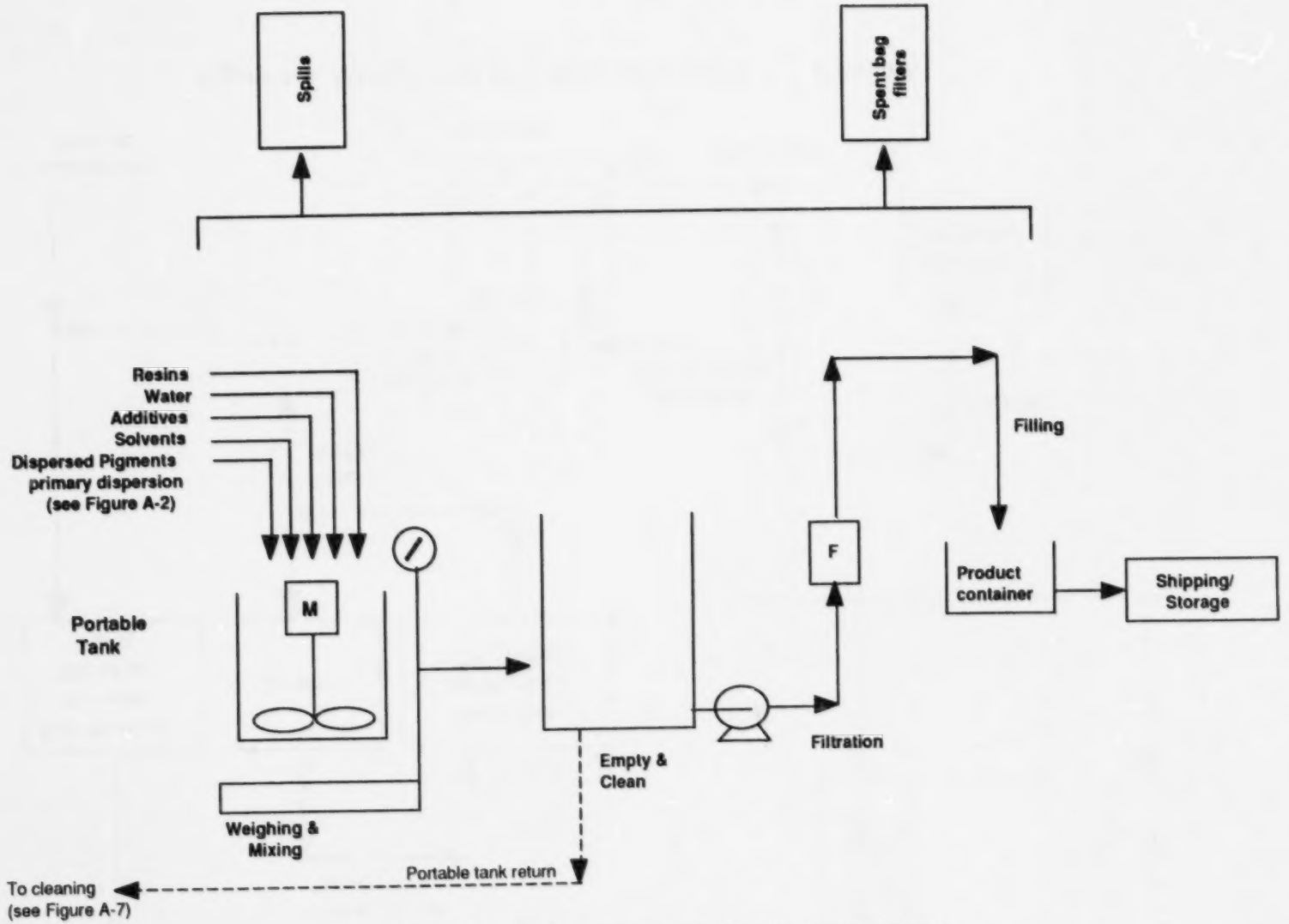


Figure A-5. Let-Down Operation for Portable Tanks at Plant A.

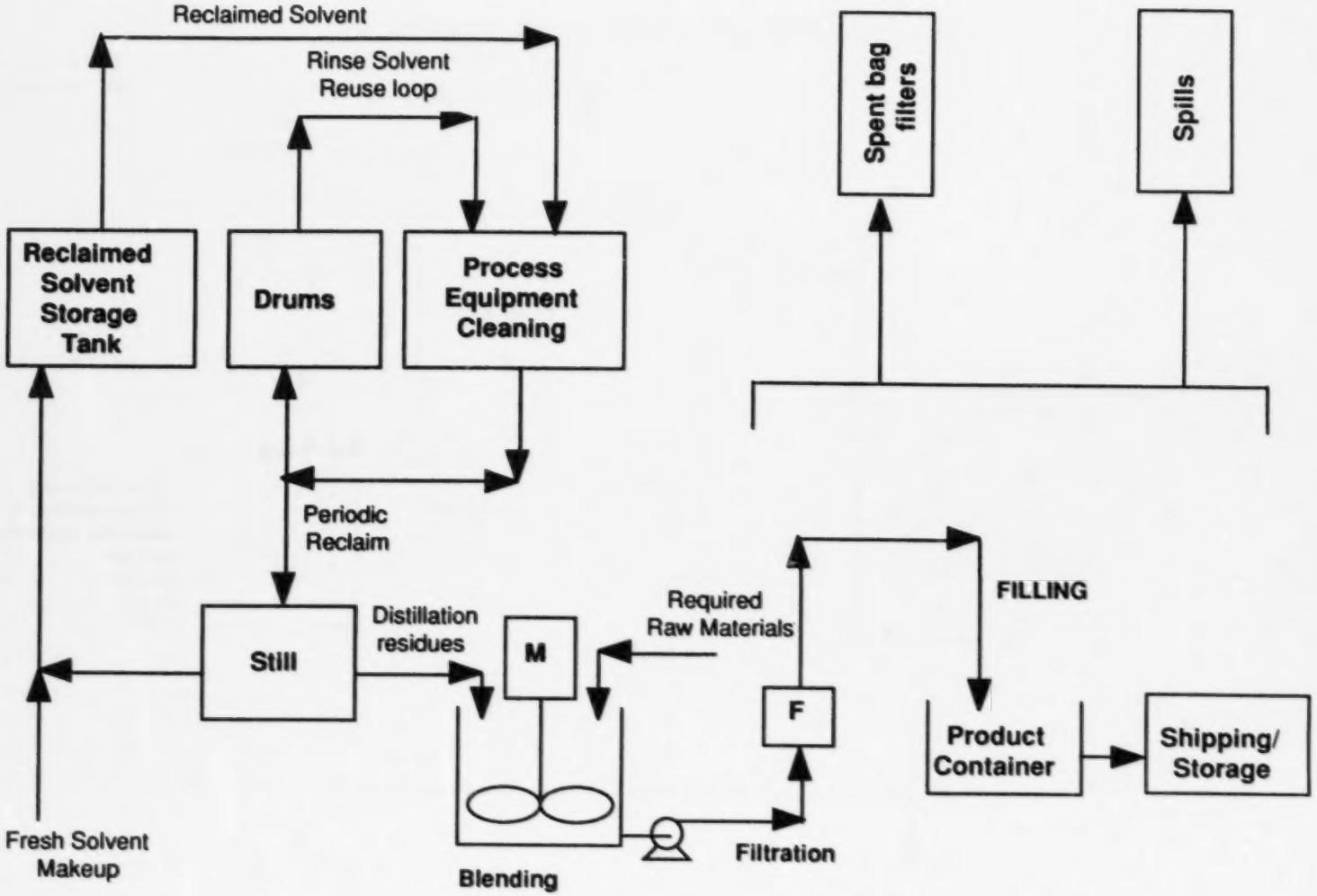


Figure A-6. Management of Solvent Cleaning Waste at Plant A.

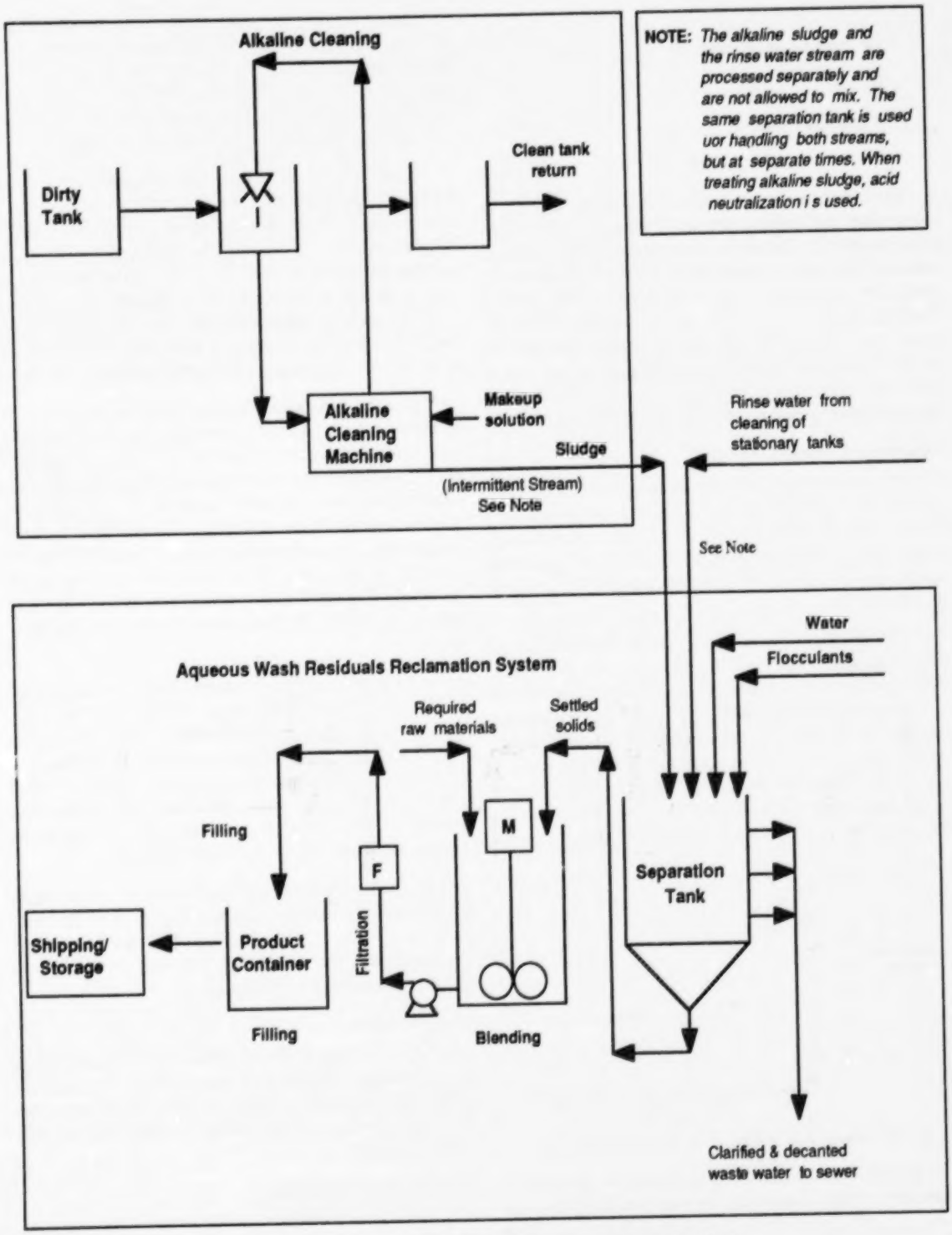


Figure A-7. Alkaline Cleaning of Portable Tanks and Aqueous Wash Residuals Reclamation at Plant A.

- Returns from customers
- Off-specification products
- Spills
- Spent filter bags
- Empty bags and packages

Table A-2 shows the various waste streams along with their origin and treatment/disposal methods used in the past and present. The waste generation rates for individual streams could not be established. Figure A-8 shows the amount of waste landfilled by Plant A since 1982. As seen from this figure, landfill disposal is no longer employed. From Table A-2, it is seen that the waste management methods have evolved into the present state, where most of the wastes are recycled, reused, or reworked. The following sections discuss each of these waste streams.

Equipment Cleaning Wastes

The process equipment is routinely cleaned to prevent product contamination and/or to restore operational efficiency. The resulting cleanup residuals constitute a major waste stream generated by the facility. Most of the cleanup wastes generated at Plant A are reprocessed into marketable products.

Mill cleaning. The mills are dedicated to a single type of product whenever possible. In such cases, post-batch cleaning of the mills is not necessary. If dedication of a mill to a single product is not possible, e.g. due to demand fluctuation, then cleaning is necessary. Cleaning is accomplished by flushing the mill either with water or a solvent, depending on the batch. The flush is then mixed with the batch in the let-down step. Thus, mill cleaning does not produce a disposable waste at Plant A.

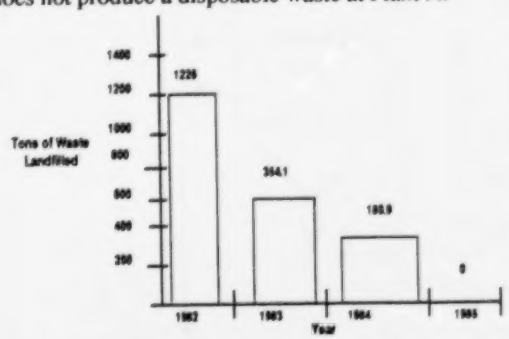


Figure A-8. Amount of Waste Landfilled by Plant A since 1982

Portable tank cleaning. Portable tanks are first scraped manually to remove residual clingage. Next, the tanks are washed with high pressure jets of a commercially available alkaline cleaning solution. The cleaning solution is recirculated and the blowdown or purge is sent to wastewater treatment. This process consists of flocculation and pH adjustment. The clear water effluent is drained to the sewer, and the settled solids containing 70 to 75 percent water are sent to a blending tank (see Figure A-7). Blending with new material produces a beige-colored coating which is sold as a general purpose coating.

Stationary tank cleaning. The stationary tanks are to a large extent dedicated to the making of a single product. In such cases, the residue on the tank walls (clingage) is allowed to build up to a certain thickness, before being scraped off manually. Following the manual cleaning, no further rinsing is necessary. The scraped paint residues were drummed and disposed of in a landfill until September 1986. Since that time, Plant A has developed a process to rework these residues into a useful product.

Non-dedicated tanks are rinsed with high pressure jets of water or hosed with solvent depending on whether the tank is used for water- or solvent-based product preparation. The rinse water is sent to a holding tank where it is blended with other aqueous wash streams to produce a general purpose paint following flocculation and pH adjustment. The rinse solvent is reused several times and then sent to an on-site still, where the solvent is recovered for reuse. The distillation bottoms are converted into a primer product by blending with solvents and other additives.

Filling unit cleanup. Separate filling units are used for water- and solvent-based paints. Filling units for water-based products are rinsed with water. The rinse water is sent for treatment as described previously. The filling lines used for solvent-based paints are back-flushed with a compatible solvent into the tank from which the product was drawn. The spent solvent is then reused or sent to the solvent recovery still, as described previously.

Container cleaning. The small containers (cans, pails, etc.) containing residual paint are sent for metal reclamation without any on-site cleaning. Containers in which mercury-based bactericides are delivered are returned to the supplier without any cleaning.

Obsolete Stock

Obsolete stock is the paint that is no longer marketed or raw material that can no longer be used. The obsolete paints that are made by Plant A are reworked into other marketable products. The obsolete raw material is returned to the suppliers.

Returns From Customers

As with the obsolete stock, the returns from customers are reworked at Plant A into other products and the empty containers are sent off-site for metal reclamation.

Table A-2. Origin and Treatment/Disposal of Paint Manufacturing Process Wastes at Plant A

No.	Waste Description	Process Origin	Treatment/Disposal Method				
			Before	1983	1984	1985	1986
1	Equipment cleaning wastes	Solvent cleaning of process equipment	D	E	A	A	A
		Water cleaning of process equipment	F: before 1976 G: started in 1976	G,H	B	B	B
		Alkalinecleaning of Process Equipment	F: before 1976 G: started 1976	G, H	B	B	B
		Mechanical cleaning of process equipment	C	C	C	C	C
2	Obsolete stock	Paint that is no longer marketed or out-dated raw materials					B
3	Returns from customers	Unused or spoiled paints returned by customers					B
4	Off-spec. products	Spoiled batches					B
5	Spills	Accidential discharges			B	B	B
6	Filter bags	Filtration of paint	I	I	I	I	I
7	Empty bags and packages	Unloading of pigments and other additives into mixing tanksNotes:	I	I	I	I	I

A-Reused to the extent possible, distill on-site to recover solvent, rework still bottoms
B-Blend to make a marketable product
C-Landfill disposal (Discontinued in September 1986)
D-Off-site recycling
E-Same as A except that the still bottoms are land disposed
F-Overflow discharge to the sewer and landfill disposal of the solids settled in weirs
G-Flocculation followed by discharge of decanted water to the sewer and landfill disposal of the settled solids
H-Vacuum filtration
I-Sanitary landfill after washing

Off-Specification Products

Off-specification products are the result of bad batches that are caused by errors in batch formulation or the failure of quality control to detect off-specification raw materials. At Plant A, the off-specification products are reworked into other usable products.

Spills

Spills are inadvertent discharges that occur at various places in the plant. At Plant A, the spills are scooped up to the fullest extent possible. If the scooped up materials are water-based then they are sent to the water treatment unit. If they are solvent-based then they are sent to the solvent recovery still. The spills that cannot be scooped up are cleaned with commercially available adsorbents. The use of "dry" cleaning methods over manual scooping is discouraged, since it is difficult to rework the adsorbents containing the spilled material.

Filter Bags

Plant A uses bag filters for all filtering applications. Cartridge filters are not used due to the associated disposal problems. The spent bag filters (used for both water- and solvent-based products) are washed and dried and disposed of as non-hazardous waste.

Empty Bags and Packages

Plant A has eliminated the use of all hazardous lead and chromate pigments, as most of the paints produced by Plant A are for use by the general public. Therefore, the presence of residual pigments does not make the bags/packages hazardous and thus they are disposed of as non-hazardous waste. In addition, since the pigments used at Plant A are mostly in slurried form, the use of pigments in bags and packages is limited.

Assessment Phase: Option Generation

The consultants reviewed the plant operations data obtained prior to and during the site inspection. They developed a set of waste minimization options based on this information and on information in the literature. These options were screened for their effectiveness in reducing waste and for their future implementation potential. The plant manager participated in this screening, with the result that there was general consensus on the list of recommended options.

SOURCE REDUCTION MEASURES

The following paragraphs describe the application and use of source reduction measures to various waste streams at Plant A.

Equipment Cleaning Wastes

This stream constitutes a large portion of the total waste generated. The following source reduction measures are in current use:

Replacement of caustic cleaning solution

In the past, the portable tanks and small containers were cleaned with caustic solution. Three years ago, the caustic cleaning solution was replaced by a proprietary alkaline solution. As the replacement frequency of this cleaning solution is half that of the regular caustic solution, the cleanup residuals' volume was cut nearly in half.

Use of high-pressure spraying systems

In the past, the water-based process equipment was rinsed clean with water from low-pressure hoses. Since this procedure generated a large quantity of wastewater, a portable high pressure spraying system was purchased. This modification contributed to a reported 25 percent reduction in cleanup waste volume.

Dedication of let-down tanks

The let-down tanks that make white paints are dedicated to making whites alone which minimizes the intermediate washing of these tanks. The deposits in the stationary tanks are allowed to build up for a period of time and then are scraped off manually. Dedication of the stationary tanks contributed to a reported 5 to 10 percent reduction in associated cleanup waste volume, when compared to a previous situation where the tanks were not dedicated and hence required cleaning after each batch.

Proper batch scheduling

At Plant A, certain batches are sequenced in the order of light to dark paint manufacture. This scheduling often eliminates the need for intermediate cleanup steps.

Pigment substitution

Plant A has already eliminated the use of lead and chromium pigments, since these pigments are prohibited from use in consumer products.

The only place where a future raw material substitution will reduce the degree of hazard is for mercury-based bactericides. Non-mercury-based bactericides have replaced mercury-based counterparts in all solvent-based paints but not in water-based formulations. Plant A continues to use mercury-based bactericides for water-based paints since their search for effective non-mercury substitutes was unsuccessful. It is suggested that the search for the substitutes should continue in spite of continual setbacks.

Obsolete Stock

Prevent obsolescence of raw material.

Prevention of raw material obsolescence is accomplished by careful control and monitoring of the inventory. The raw material is used up as quickly as possible to avoid expiration or degradation. The raw materials are accepted from the suppliers only when they meet stringent quality control standards. When a raw material becomes obsolete, it is returned to the supplier.

Prevent obsolescence of finished stock

Obsolete finished material can be virtually eliminated by proper production planning and inventory control. The current manual inventory control system is very efficient in limiting the obsolete stock. The company is planning to purchase a computerized raw material inventory control system. The computerized system is expected merely to provide more detailed information about the inventory in a shorter time period.

Off-specification Products

The off-specification products are reworked on-site to produce marketable products. To achieve additional savings in reprocessing cost, however, reduction of off-specification product generation can be further promoted by proper quality control of the raw material, increased process automation, and by ensuring effective cleanup of equipment. Tight control measures have been extremely effective at Plant A.

Spills

As mentioned previously, the spills are first recovered by manual scooping, then reworked into useful products. Only the residuals remaining after the recovery are subject to "dry" cleaning using adsorbents. Direct use of adsorbents (i.e. without prior recovery) is discouraged as the resulting waste is difficult or impossible to reprocess.

Filter Bags

The use of cartridge filters was eliminated since their disposal proved problematic. Plant A, at present, uses bag filters for all purposes. These filters are reused to the extent possible. The spent bag filters when rinsed and dried are not considered hazardous waste.

Empty Bags and Packages

Use of non-hazardous pigments.

As none of the pigments used at Plant A are hazardous, the empty bags and packages containing residual amounts are not considered hazardous.

Use of pigments in slurry form.

Most of the pigments used by Plant A are in slurry or paste form, and therefore, the use of bags and packages for pigments is minimal.

Use of water-soluble bags.

Some of the mercury-based bactericides are delivered to Plant A in water-soluble bags. These bags are added to the batch along with the bactericides, thus avoiding the generation of waste in the form of empty bags and packages.

RECYCLING AND RESOURCE RECOVERY MEASURES

Waste segregation, on-site recycling, and off-site recycling were evaluated for their effectiveness in reducing waste generation at Plant A. These are discussed in the following paragraphs.

Waste Segregation

Segregate water- and solvent-based wastes.

The solvent-based equipment cleanup wastes are segregated from the water-based wastes. This facilitates the rework of both these streams into marketable products. The solvent- and water-based wastes are reworked as shown in Figures A-6 and A-7, respectively. The rework strategies shown in these figures would not be effective if the waste streams are allowed to mix.

Segregate alkaline cleanup wastes from rinse water wastes.

The alkaline cleanup wastes are segregated from rinse water wastes. Both these waste streams are separately reworked (see Figure A-7) into useful products.

On-site Recycling

Reuse of water-based equipment cleanup wastes.

In the past, partially dewatered cleanup wastes were landfilled. Ten years ago a flocculation step was introduced to remove the solids prior to discharging the stream to the sewer. The flocculated solids containing 70 to 75 percent water were disposed of in landfills. Six years ago this procedure was again modified by adding a vacuum filter to reduce the water content in the disposed solids to 30-35 percent.

Since all these process modifications still involved disposal of solids in a landfill, Plant A decided to pursue other process changes that would eliminate such disposal. This decision was based, in part, on anticipated landfill ban. Currently, the water-based equipment cleaning wastes are blended with additives after flocculation to generate a beige-colored product (see Figure A-7) which is sold as a general purpose paint. Thus, by rework, the landfilling of water-based equipment cleanup wastes is avoided altogether.

Reuse of alkaline cleaning wastes.

The alkaline cleaning of portable tanks generates a waste stream. This stream is segregated from the aqueous wastes described in the previous paragraph, but processed in the exact same manner (flocculation, pH adjustment and blending) to produce a marketable product (see Figure A-7).

Reuse of solvent-bearing cleanup wastes.

The cleanup solvents are reused several times for rinsing tanks. This procedure ensures that the total solvent usage for cleaning is minimized. When the rinse solvent is considered too dirty for direct reuse, it is distilled on-site. The solvent reclaimed by distillation is recycled to the cleaning operation. The distillation bottoms are sent to a holding tank, where they are blended with solvents and other raw materials to produce a primer product (see Figure A-6).

Rework wastes.

All of the wastes due to customer returns, scraped paint residues, obsolete finished products, off-specification products, and scooped up spills are reworked into marketable products. Proper identification of the customer returns is central to determining the rework strategy for this waste. For the scraped paint residues (generated due to the mechanical cleaning of stationary and portable tanks), Plant A has developed a process to rework these residues into a useful product. This process is currently being refined.

Off-site Recycling

In the past, the solvent-based cleanup wastes were sent to an off-site recycler for reclamation. The reclaimed solvent was purchased from the recycler and reused. As this process proved expensive, Plant A discontinued off-site recycling four years ago in favor of on-site recycling. At present, off-site recycling is practiced only on an occasional basis.

Feasibility Analysis Phase

The recommended options were evaluated for their technical and economic feasibility by the consultants, who obtained cost and performance data from vendors where new equipment was recommended. The result of the technical and economic feasibility analyses was a list of feasible options, which became part of the assessment's final report. The next waste minimization assessment phase, Implementation, was left to the discretion of the paint manufacturer, Plant A.

The specific economic aspects of implementing each of the source reduction/resource recovery options were not separately documented by Plant A. Most of the source reduction options employed are essentially good operating practices, and hence did not require a large capital investment. However, the rework strategies and their evolution did require a large R&D expenditure. The implementation of these measures seemed to be guided more by the intuition and foresight of the plant personnel than by the calculated benefits that may have been indicated by a specific detailed economic evaluation.

The plant personnel indicate that the increase in operating expense for rework has been matched by the increased revenues due to the sale of reworked products. The avoided disposal costs, however, are expected to be quite significant. In 1984, 181 tons of waste (equivalent to about 660 fifty-five gallon drums) was landfilled (see Figure A-8). In 1985, due to a comprehensive rework strategy, no waste was landfilled. Using landfill disposal costs of $155/drum, Plant A saved $102,000 in avoided disposal costs as compared to 1984. By reducing its waste from the 1982 level of 1226 tons landfilled, over the years 1983-1985 Plant A avoided paying a total of $1.78 million in landfill disposal costs. This assumes that waste generation would have remained constant without waste minimization -- a conservative assumption since production rates actually increased somewhat.

RATING OF WASTE MINIMIZATION MEASURES

Table A-3 lists the various source reduction measures noted above for each waste stream. Table A-4 lists the recycling and resource recovery options. Each measure is qualitatively rated on a scale of 0 (low) to 10 (high) for its waste reduction effectiveness, extent of current use, and future application potential. The waste reduction effectiveness indicates the amount of waste reduction that is possible by implementing a particular source reduction/recycle measure. The extent of current use, as the name implies, is a measure of current usage of a particular waste reduction option. The future application potential is a qualitative measure of the probability that the measure would be implemented in the future. This probability is a function of the cost, degree of technical risk, and the extent of current use.

Because most of the waste minimization methods presented in this report are already in use to a large extent at Plant A, the future reduction index is low in most cases. The following source reduction measures are currently used by Plant A to a large extent: pigment substitution, proper batch scheduling, dedication of process equipment, preventing obsolescence of raw material, ensuring proper batch formulation, and washing and drying filter bags prior to disposal.

The extensive rework of wastes is responsible for zero

Table A-3. Summary of Source Reduction Measures for Plant A

Waste Source	Control Methodology	Waste Reduction Effectiveness	Extent of Current Use	Future Application Potential	Current Reduction Index		Future Reduction Index
Equipment Cleaning Wastes	1. Replacement of caustic cleaning solution	9	9	1	8		0
	2. Use of high-pressure spraying systems	7	8	3	6		0
	3. Dedication of let-down tanks	9	10	0	9		0
	4. Proper batch scheduling	9	10	0	9		0
	5. Pigment substitution	10	10	0	10		0
	6. Use of non-meercury bactericides	10	0	8	0	==>	8
Obsolete Stock	1. Prevent raw material obsolescence	10	10	0	10		0
	2. Prevent finished stock obsolescence	10	10	0	10		0
Off-Spec Products	1. Ensure proper batch formulation	10	10	0	10		0
Spills	1. Discourage dry cleanup methods	9	9	1	8		0
Filter Bags	1. Wash and dry before disposal	10	10	0	10		0
Empty Bags & Packages	1. Use non-hazardous pigments	10	10	0	10		0
	2. Use of pigments in slurry or paste form	8	8	5	6	==>	1
	3. Use of water-soluble bags	5	10	0	5		0

Table A-4. Summary of Recycling and Resource Recovery Measures for Plant A

Recycling/Resource Recovery Measure	Control Methodology	Waste Reduction Effectiveness	Extent of Current Use	Future Application Potential	Current Reduction Index	Future Reduction Index
Waste Segregation	1. Segregate water and solvent wastes	10	10	0	10	0
	2. Segregate water and alkali wastes	10	10	0	10	0
On-Site resycling	1. Reuse rinse water wastes	10	10	0	10	0
	2. Reuse alkaline cleanup wastes	10	10	0	10	0
	3. Reuse solvent-10 bearing cleanup wastes	10	0	10	0	
	4. Rework wastes	10	10	0	10	0
Off-Site recycling	1. Off-site reclamation/ incineration	2	1	0	0	0

waste generation at present and therefore given a zero future reduction index in Table A-4. The use of non-mercury bactericides and the use of pigments in slurry or paste form are rated high for future application potential. These two measures, however, have a very low impact on reducing waste volume because these processes generate only a small volume of waste.

SUMMARY

The data on production and waste generation rates for Plant A for 1982 to 1985 can be used to determine specific waste generation rates (lb waste/gal product). These rates are plotted in Figure A-9. The waste reduction program used by Plant A is clearly effective; the specific waste generation rate was reduced from 0.34 lb/gal in 1982 to zero in 1985. The following factors contributed to this successful waste reduction effort at Plant A:

- Proper planning and foresight. The problems associated with off-site waste disposal were anticipated well in advance and measures were implemented ahead of time. Total elimination of landfill disposal was a goal set by management. Waste minimization and other environmental issues are given high priority.
- Proper perspective of the waste minimization issue. Good operating practices contributed to successful source reduction, recycling, and reworking of all the wastes generated. The research and development effort resulted in the formulation of new products from the waste and at the same time reduced the need for disposal.
- Experienced employees. The average seniority is well over 10 years for the employees at Plant A. Because the employees understand the process very well, mistakes that result in waste generation are few and infrequent.
- Product usage. Most of the paints produced by Plant A are for use by the general public. For this reason, extreme care is taken in the choice of raw material and product formulation. This is seen in the rapid replacement of solvent-based formulations by water-based formulations in the architectural paints category in the last decade.
- Product variety. Most of the paints produced at Plant A are water-based latexes and blending of waste latexes to produce a marketable product is easier than for non-latex paints. Hence, waste reuse, by blending, to produce a marketable product may not be a viable option for industrial paint manufacturers who produce solvent-based acrylics, epoxies, urethanes and other products.
- Marketing outlets. Plant A markets its products through retail outlets and commercial service centers. Any new product resulting from reworking processes can be easily sold from these outlets using price discount programs. Also, because home interior paint is purchased for aesthetic rather than functional attributes, consumers are more liberal in experimenting with new products. The same advantage may not pertain to industrial paint manufacturers, where the functions of the products limit their usage and marketability.

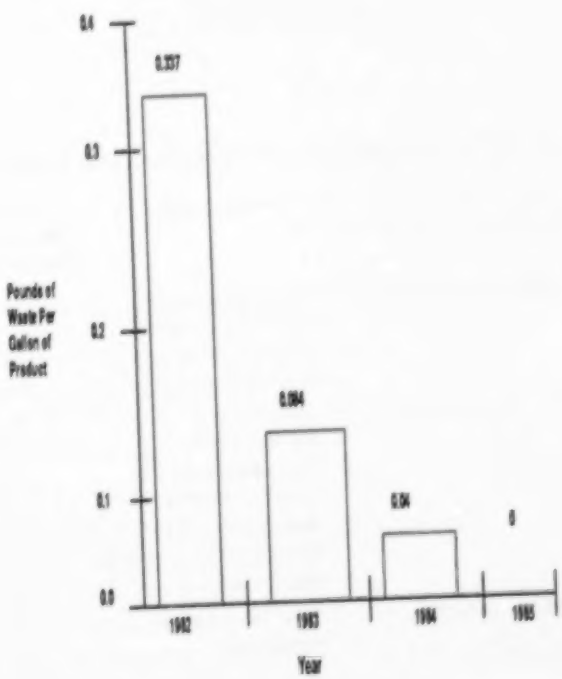


Figure A-9. Specific Waste Generation Rates for Plant A Since 1982.

Reference

DHS. 1987. *Hazardous Waste Minimization Audit Study of the Paint Manufacturing Industry*. April 24, 1987. Prepared for California Department of Health Services, Alternative Technology Section (Sacramento, California) by Jacobs Engineering Group Inc.

PLANT B WASTE MINIMIZATION ASSESSMENT

The waste minimization assessment of Plant B followed the same protocol used for Plant A, and included:

- Planning and organization
- Assessment phase
- Feasibility analysis phase

Implementation of selected waste minimization options was left to the discretion of Plant B.

Planning and Organization

Planning and organization of the assessment were a joint effort of the consulting firm and the paint manufacturing plant's operations manager. As summarized in Figure 1, this phase of the assessment involved getting company managment commitunent to the project, setting goals for the assessment, and establishing a task force (the consultants working in cooperation with the plant operations manager) to conduct the assessment.

Assessment Phase: Process and Facility Data

The consultants worked with the plant operations manager to establish a data base of the facility's raw material needs, materials handling procedures, and operations processes. Block flow diagrams were drawn up to identify where materials are used and where waste is generated. Initial study of this information and discussions of waste stream concerns at the plant served as preliminary steps to the site inspection, during which additional process and waste handling information was obtained.

FACILITY DESCRIPTION

Plant B produces a wide variety of industrial coatings. About 90 percent are solvent-based; the remainder are water-based. About 10 years ago, the water-based paints constituted only 1 percent of total production.

The solvent-based paints produced include pigmented tints, pigmented non-tints, lacquer thinners, unpigmented paints (clears), and stains. The water-based formulations are mostly emulsion paints. The production rates of the major products are listed in Table A-5.

Table A-5. Coatings Produced by Plant B in 1985

Product	Production Rate (gal/yr)
Pigmented products (enamels)	360,000
Clear products (lacquers & varnishes)	1,220,000
Reducers & solvents	260,000
Stains & fillers	310,000

RAW MATERIALS MANAGEMENT

Numerous organic solvents are used at Plant B in paint production. Other raw materials in paint production include resins, pigments, extenders, and additives. Table A-6 presents the consumption rates of the major raw materials in 1985.

The selection of solvents used in paint production is based on the end use of the paint. The solvents used at Plant B include methanol, methyl ethyl ketone (MEK), Tolusol-6, toluene, lacquer thinner, and mineral spirits. The solvents are purchased in bulk or in drums. The solvents in bulk form are stored in underground storage tanks. The solvents in drums are stored in an outdoor storage area.

The pigments are delivered in plastic or paper bags, which are stored in an indoor storage area. The inventory is typically capable of meeting the production requirement for two months. In addition to raw materials, some process intermediates are also stored indoors.

Each of the raw materials is assigned an identification number for inventory control and product formulation. The amounts of various raw materials for each batch are determined through a computer and the data is punched out on computer-generated batch cards. The employee at the production unit follows the instructions given on the cards and obtains the raw material from the storage area using the coding sequence for the material.

PROCESS DESCRIPTION

The following description highlights the production of a solvent-based paint at Plant B. The block flow diagram for this process is presented in Figures A-10 through A-12.

The production of the paint begins with dispersing the pigments in either a roll mill or a sand mill. The sand mills are horizontal or vertical and employ sand/glass/steel bead/shot to disperse the pigments in a small quantity of solvent/resin mixture. The primary dispersion is carried out in batches of 30 or 55 gallons. After passing through the mill, the mixture of pigments and solvent/resin is collected in another container and sent to intermediate storage, let-down, or the next step in production. Sometimes, the mixture is passed through the mill up to 3 times to achieve the required degree of dispersion. In such instances, two containers (feed container and receiver container) are used. The same containers are used for all the passes through the mill, and the containers are cleaned after each pass.

Table A-6. Raw Material Consumption Rates at Plant B in 1985

No.	Material	Annual Consumption Rate
Solvents		
1.	Methanol	48,000 gal.
2.	Methyl ethyl ketone	178,000 gal.
3.	Tolusol-6	361,000 gal.
4.	Solvent IB	186,000 gal.
5.	Lacquer thinner (blend)	170,000 gal.
6.	Mineral spirits	132,000 gal.
7.	Filmcol A-4	82,000 gal.
8.	Isobutyl Isobutyrate	51,000 gal.
Resins		
9.	Beckosol	41,515 gal.
10.	Coconut Alkyd	33,575 gal.
11.	Rhophex WL-91	16,000 gal.
Pigments		
12.	Titanium dioxide	350,000 lbs.
13.	Yellow oxide	32,000 lbs.
14.	Burnt umber	51,000 lbs.
15.	Van dyke brown	56,000 lbs.
Extenders		
16.	Calcium carbonate	52,000 lbs.
17.	Talc	128,000 lbs.
18.	Clay	30,000 lbs.
Miscellaneous		
19.	Drying oils	30,000 gal.
20.	Plasticizers	10,000 gal.

The let-down step consists of filling the mixing tank with the primary dispersions, solvents, plasticizers and other additives. The solvents are pumped into the tanks using the filling system shown in Figure A-13. The contents are then mixed. For portable tanks, high-shear vari-speed mixers are employed. For the stationary tanks a low-speed mixing is used. When the tank contents attain the proper viscosity, color, and gloss, the mixing is stopped and the contents are filtered and dispensed into product containers. The filtration is achieved using bags, cartridge filters, or vibrating screens. If the tanks are portable, they are moved to the filling area and the contents are gravity fed to the filling unit.

The batch sizes are 55, 110, 220, 300 or 550 gallons for the portable tanks. Larger batches are prepared in stationary tanks with a capacity of 1000, 1500, or 3000 gallons. Figure A-13 shows the layout of the tanks in the production area. The stationary tanks are usually dedicated to one product and therefore, no cleaning is required between subsequent batches. At present, the products prepared in the stationary tanks (in order of decreasing production quantity) are clears, stains, and enamels. Similarly, the major products produced using portable tanks are stains, enamels, and clears.

WASTE DESCRIPTION

The major wastes generated by Plant B are (in order of decreasing volume): equipment cleaning waste, obsolete products, returns from customers, off-specification products, spills, filter bags and cartridges, and empty bags and packages. The sections below discuss each of these wastes.

The solvent waste is sent to an off-site recycler for reclamation. On-site solvent recovery was conducted in the past, but was discontinued when it proved too expensive. The off-site recycler charges $0.65/gal of spent solvent to reclaim it at 60 % minimum yield and return it to Plant B. The distillation residues generated during the reclamation are disposed of at a surcharge of $0.75/gal-spent solvent. The off-site recycler charges $1/gal if the solvent waste is incinerated in a cement kiln. The off-site recycler is planning to substantially increase its service charges (e.g. $ 2.60/gal for incineration) in the near future.

Table A-7 presents the costs ($/ton) of some solvents used by Plant B. Also presented are some disposal cost figures from an off-site recycler.

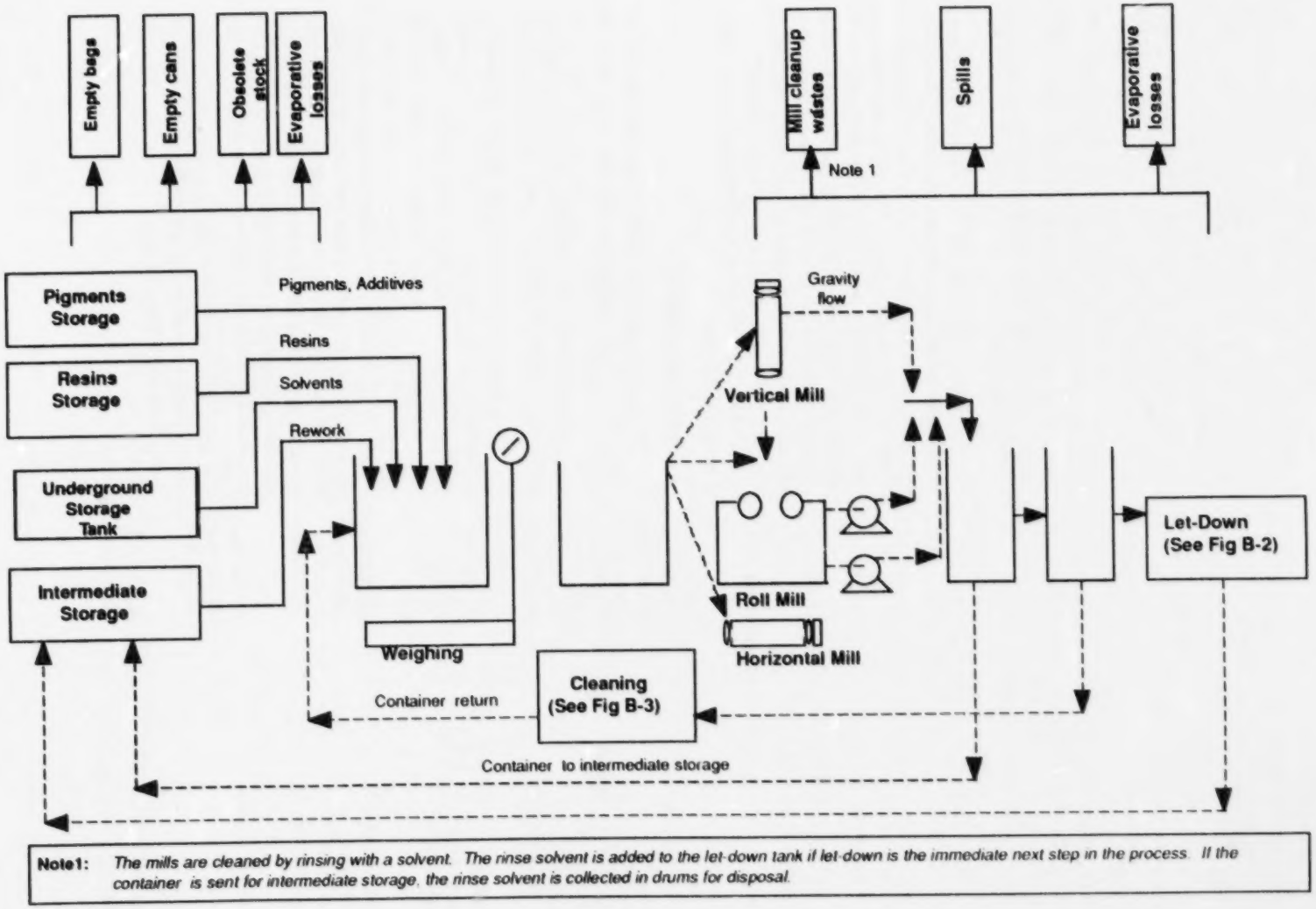


Figure A-10 Primary Dispersion Process for Paint Manufacture at Plant B.

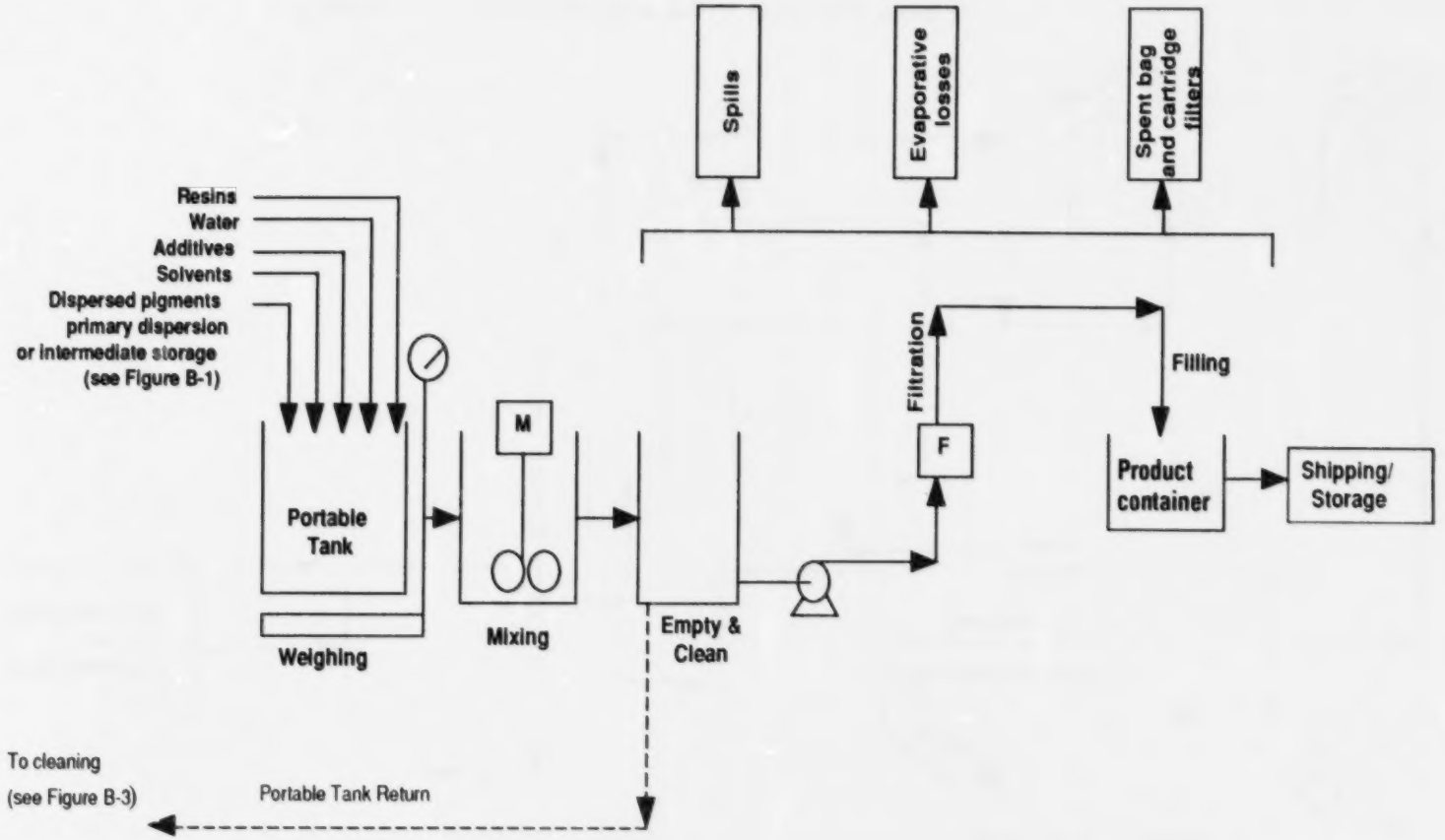


Figure A-11 Let-Down Operation for Portable Tanks at Plant B.

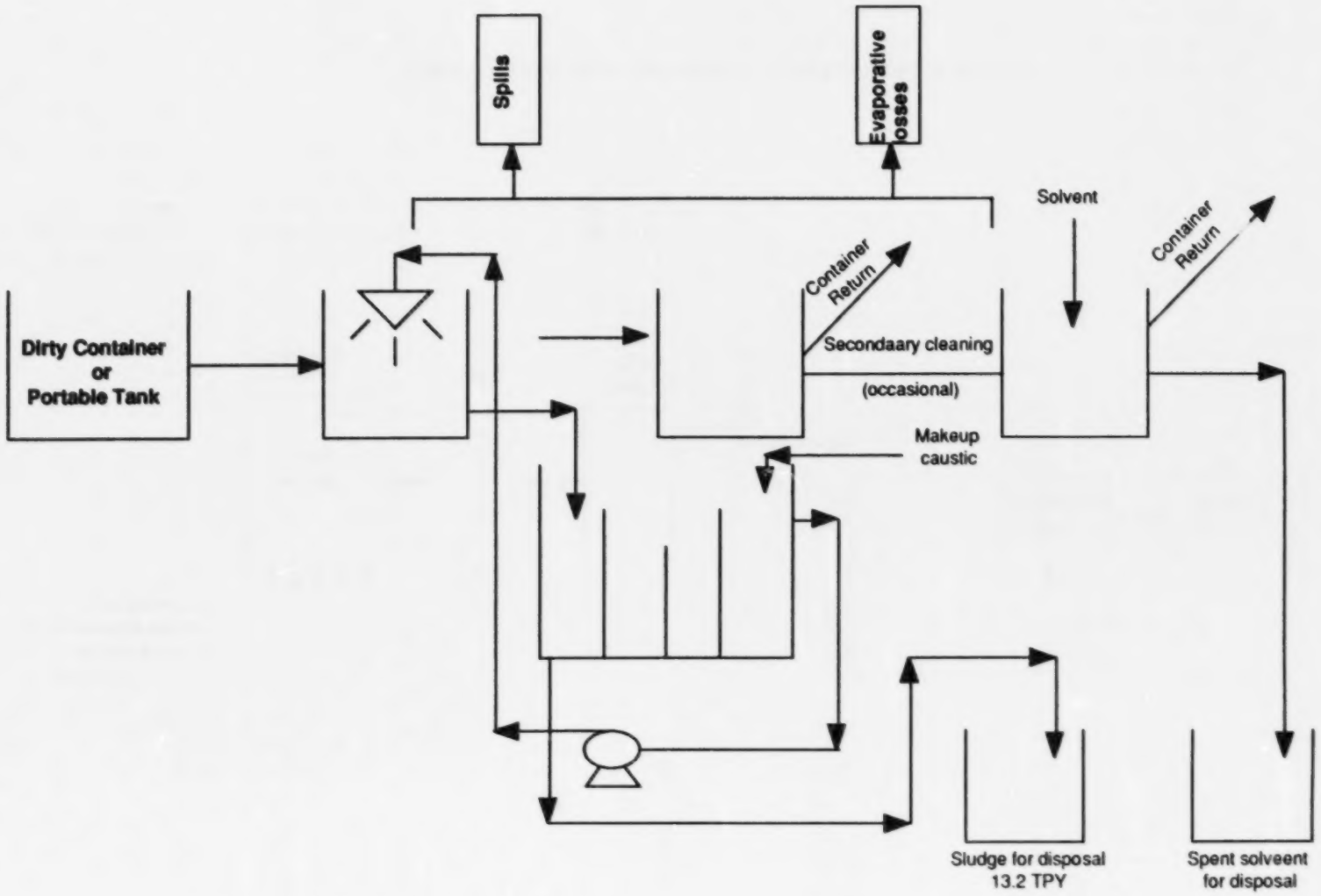


Figure A-12 Container Cleaning Operation at Plant B.

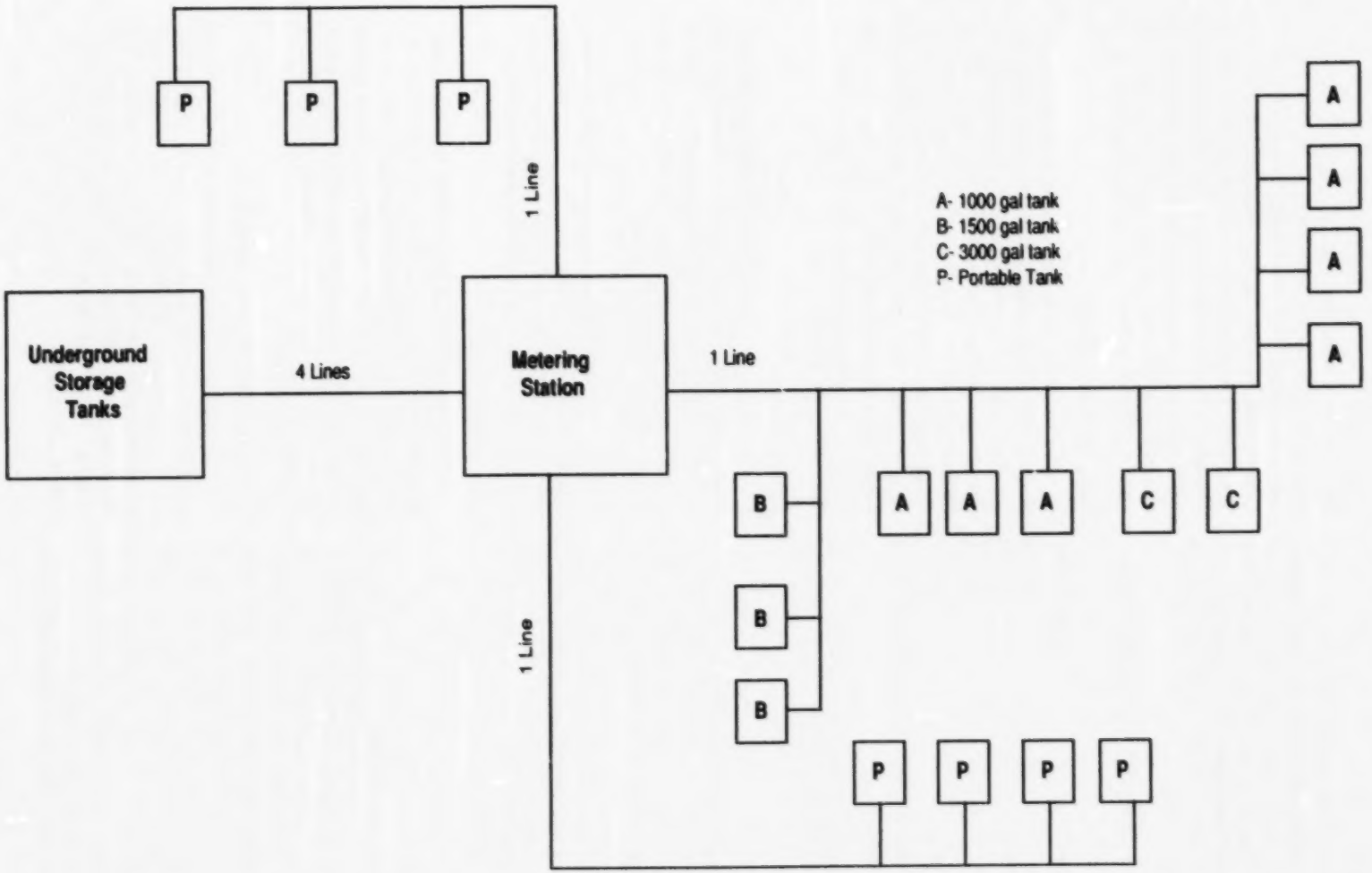


Figure A-13 Lay-out of Solvent Input Lines at Plant B.

Equipment Cleaning Wastes

Equipment such as mills and mixing tanks is cleaned after each batch in order to prevent cross-contamination. Unusable storage containers, such as drums and pails, are cleaned before sending them for off-site metal reclamation. The equipment cleaning generates two waste streams: spent solvent from solvent rinsing operations and paint sludge from caustic cleaning.

Table A-7. Raw Material Costs and Waste Disposal Costs

No.	Solvent/Waste	Cost ($/ton)
1.	Lacquer thinner	386.00
2.	Methyl ethyl ketone	470.00
3.	Mineral spirits	204.00
4.	Recyclables (a)	280.00
A.	Incinerables (a,b)	200.00

Notes: (a) A density of 10 lb/gal was assumed for liquid wastestreams.

(b) Indicates price charged by an off-site recycler in 1985 and does not include lost raw material costs.

Mill cleaning

The mills are usually cleaned with a solvent used in formulation of the next batch. When this is not possible, methyl ethyl ketone (MEK) is used for cleaning. The cleaning solvent is let through the operating mill immediately following the batch. The spent MEK is reused if contamination is not a problem. Spent solvents from mill cleaning operation are used directly as part of formulation if let-down step immediately follows milling. In cases where the intermediate dispersion is stored for later use, the flush solvents are collected and reclaimed off-site by an off-site recycler.

Portable tank cleaning

Manual cleaning with spatulas is used to remove clingage from portable tanks before cleaning with a caustic solution. The removed clingage is drummed and sent for off-site incineration. Following clingage removal, the portable tanks (and barrels/pails) are cleaned in a caustic cleaning machine employing a high pressure spray. Generally, the tanks are cleaned immediately after use to prevent drying of the residues on the tank walls. When cleaning cannot be performed immediately after clingage removal, a small quantity (e.g. one quart) of solvent is added to the tank to prevent drying of residuals. This solvent is either lost due to evaporation or removed by the caustic cleaning. The caustic cleaning solution comprises 600 gallons of water with 475 lbs of dissolved sodium hydroxide at 200-205 F. The caustic solution is recirculated and the sludge drawn off into reclaim drums for disposal through off-site incineration. In 30 percent of the cases, the caustic wash alone is insufficient, and further cleaning with a solvent (such as MEK or lacquer thinner) is required. The solvent wash residuals are drummed and sent off-site for solvent reclamation. This additional cleaning is common for handling acrylic paint deposits. Plant B is installing a new high pressure nozzle to improve the cleaning efficiency of the caustic cleaning system.

Stationary tank cleaning

The stationary tanks are usually dedicated to the production of a single product. In such cases, the tank walls are rinsed with the solvent used in the formulation. The rinse solvent then becomes part of the next batch. When a different product is to be prepared in the tank, the tank is rinsed with three gallons of lacquer thinner before starting the new batch. The spent solvent is reused for rinsing whenever possible. When this is not possible, the spent solvent is drummed and sent to the off-site recycler for reclamation/incineration.

Filling unit cleanup

The filling unit consisting of a positive displacement pump, filter, and associated piping, is solvent-cleaned between filling campaigns of different products. Prior to solvent cleaning, the residual paint is emptied from the suction side into a container using the pump. The residual paint from inside the filter housing and the discharge side is normally drained into a separate bucket, and combined with the product. MEK is then used for rinsing the filling unit. The spent MEK is reused if possible or drummed and sent to an off-site recycler for reclamation/incineration.

Turbine mixer cleaning

The turbine mixers used for let-down in portable tanks are also solvent cleaned. Here, the mixer is lifted from the mixing tanks, lowered into a barrel containing solvent, and then rotated. The solvent in the barrel is reused several times before being sent off-site for reclamation/incineration. Prior to solvent cleaning, cleaning with brushes is sometimes employed.

Returned product container cleaning

The returned tote bins containing residual paint are cleaned by an off-site contractor. Before sending the drums, pails, and cans off-site for metal reclamation, they are cleaned either on-site or off-site. In the past, the containers could be sent for metal reclamation without any cleaning. At present, the reclaimers do not accept uncleaned containers.

Obsolete Products

Obsolete products are mostly paint that is no longer produced or marketed. These materials are usually reworked into marketable products. When this is not possible, they are sent to an off-site recycler for reclamation or incineration. Unusable shipping containers that contain some leftover paint are a part of this stream. These pails may be washed on site or sent off-site for cleaning. After cleaning, the pails are sent for off-site metal reclamation.

Returns from Customers

Unused or spoiled paints are often returned to Plant B by their clients. These returns are accepted to maintain good customer relations. After lab analysis, some of these wastes are reworked into marketable products and the remainder is sent to an off-site recycler for reclamation/ incineration. The containers that are returned by the customers are handled in the manner discussed in the previous paragraph.

Off-specification Products

Off-specification products are usually generated by any of the following occurrences:

- Errors in the computer codes for the raw materials. This can cause the operators to use the wrong materials or formulation for the batch.
- Spoiled or degraded raw materials. The raw material are routinely tested; however, time and production constraints sometimes result in the quality control steps being by-passed.
- The "rework" material may sometimes be introduced into a wrong batch.
- Contamination due to improper cleaning of the tank.

The average seniority of employees at Plant B is about 10 years and the employees have considerable experience, which makes errors in batch formulation infrequent. The off-specification products are usually reworked. When this is not possible, they are sent off-site for reclamation/ incineration.

Spills

Spills are inadvertent discharges of paint that occur in the production area. Spills are usually cleaned by "dry" methods. Saw dust or sand is sprinkled on the spill and then scraped up and drummed for disposal in a landfill. The area is then mopped with a thinner.

Filter Bags and Cartridges

The spent filter bags and cartridges are disposed in a landfill. As of November 8, 1986, this waste may not be disposed of in a landfill if the solvent content is more than 1 percent. Plant B is considering alternative disposal options including the use of an off-site incinerator.

Empty Bags and Packages

The pigments are usually delivered in paper bags. The empty bags and packages containing traces of pigments are hazardous waste and are baled and sent to a landfill for disposal.

WASTE GENERATION RATES

Table A-8 presents the individual waste streams along with their origin, treatment/disposal, and their generation rates in 1985. Generation rates for waste streams such as obsolete stock, customer returns, off-specification products and spills are not documented separately at Plant B; these figures are included in the equipment cleaning waste generation rate shown in Table A-8. The amount of solvent consumed in cleaning operations is about 1500 gallons per month, which gives a measure of the equipment cleaning wastes. The caustic wash process generates about 220 gallons of sludge per month.

Assessment Phase: Option Generation

After the site inspection, the plant operations manager and the consultant team reviewed the raw material, process, and waste stream information and developed a number of waste minimization options for consideration. These options fall into the categories of source reduction techniques and recycling and resource recovery techniques.

SOURCE REDUCTION MEASURES

Equipment Cleaning Wastes

Equipment cleaning wastes constitute the major portion of the total wastes generated by Plant B. Both existing and new source reduction measures can be effective in reducing this waste stream. These measures fall into four general categories:

- Raw materials substitution
- Process modification
- Equipment modification
- Improved operating practices

Raw materials substitution

Plant B uses lead and chromate pigments for making special primers. The use of these pigments should be

Table A-8. Origin, Treatment/Disposal , and the 1985 Generatiion Rates of Paint Manufacturing Process Wastes at Plant B.

No.	Waste Description	Process Origin	Treatment/Disposal	Generation Rates, Short Tons			
				Solvents	Solids	Sludge	Total
1	Equipment cleaning wastes	Equipment cleaning using solvent. Equipment cleaning sludges removed from the caustic cleaning solution.	Sent to OSCO for off-site reclamation/incineration	148.5	75	N/A	223.5
			Sent to OSCO for off-site incineration	N/A	N/A	13.2	13.2
2	Obsolete products	Paint that is no longer produced or marketed, obsolete raw material	Some of it is reworked & the rest is sent to OSCO	•	•	•	•
3	Returns from customers	Unused or spoiled paints returned by customers	Some of it is reworked & the rest is sent to OSCO	•	•	•	•
4	Off-specification products	Spoiled batches	Some of it is reworked & the rest is sent to OSCO	•	•	•	•
5	Spills	Accidential discharges	Dry cleanup followed by landfill disposal of the spent absorbents	•	•	•	•
6	Filter bags and cartridges	Filtration of paint	Landfilled at present, planning alternate means of disposal	1	1	N/A	2
7	Empty bags and packages	Unloading of pigments and other additives into mixing tanks	Landfilled	N/A	Unknown	N/A	0.1

Notes:

• - Data included in the equipment cleaning wastes

N/A - Not applicable

reduced or eliminated to the fullest extent possible. Equivalent formulations using less hazardous pigments are commercially available (e.g. the no-lead and no-chrome alternatives marketed by Halox Pigments) and should be tested for customer acceptance. Chrome yellow pigment can be substituted for by organic pigments or yellow iron oxide. However, the color obtained with yellow oxide pigments is not as bright when compared with chrome yellow counterparts. Customer acceptance is viewed as a major obstacle.

Process modification

- Improved production planning. The mills are usually cleaned with a compatible solvent thereby generating a stream that is used in the let-down formulation. However, this is not done if the pigments are dispersed for subsequent storage. In the latter case, MEK is used to clean the roll mill. By planning the production schedule in such a way that the pigments are dispersed only before a batch formulation (thus eliminating the need for intermediate storage), the spent MEK wastes can be minimized. Alternatively, the mills can be cleaned with a small amount of compatible solvent to be combined with the batch that is destined for intermediate storage.

- Recirculation through the mill. Recirculating the mixture of pigments and solvent through the mill and returning them to the same container should be explored. This process avoids the use of a second container for collecting the material from the mill, with the elimination of one cleaning step. This method has more potential for waste reduction in cases where multiple passes through the mills are necessary. The disadvantage of this method is that fine, dispersed pigments are allowed to mix with undispersed pigments before going through the mill again. This may reduce the efficiency of the mill and require running the mill for a longer period of time. Excessive degradation of the polymers (resins) can also be a problem with this recirculation scheme. The economics of increased power consumption should be weighed against the reduction in labor required for cleaning plus the reduced disposal costs.

- Replacement of caustic solution. The caustic solution used for cleaning can be replaced by a more stable cleaning fluid. Some commercially available alkaline cleaners were found to be an effective alternative by other users. There are no expected disposal problems associated with the use of these formulations. One such washing agent, when substituted for caustic solution at another facility, reduced the cleaning solution replacement frequency by a factor of two.

- Caustic wash sludge dewatering. The sludge generated from the caustic cleaning system is generally drummed for disposal. Dewatering the sludge by flocculation, filtration, or centrifugation can minimize this waste volume. Adding de-emulsifiers to the rinse water can also break the emulsion and decrease the sludge volume. The spent rinse water should be allowed to settle for an adequate period of time to allow for complete solids separation. It should be noted that dewatering, while effective as a cost reduction measure, has few, if any, environmental benefits.

Equipment modification

- Mechanical cleaning. Use of mechanical devices for cleaning the tanks is currently practiced only on small tanks. The paint residues are removed with a spatula before sending the tank for caustic cleaning. For larger tanks, the use of rubber/metal blade wipers appears to be limited.

- High-pressure nozzle replacement. Plant B is replacing the existing high pressure nozzle used for caustic spray cleaning with a more efficient unit. Increased cleaning efficiency will contribute to a reduction in the solvent cleaning currently necessary in some cases after the caustic cleaning.

- Replacement of existing mills. The installation of more efficient mills that would not require multi-pass dispersions should be considered as a part of future plant modernization plans.

- High-pressure cleaning of stationary tanks. The large (stationary) tanks can be cleaned by efficient high pressure cleaning systems such as the ones used by Lilly Industrial Coatings in High Point, North Carolina. This measure would decrease the total amount of solvent required for cleaning.

Improved operating practices

- Avoidance of unnecessary cleaning. Equipment should be cleaned only when necessary. For example, when the primary dispersion is done, employing more than one pass through the

mills, the containers are currently rinsed between passes. This intermediate cleanup can be avoided if the product contamination is not significant. In general, the feasibility of eliminating the cleaning step between subsequent batches should be explored. Experiments could be conducted on a small scale in the laboratory to measure the degree of contamination resulting. If the contamination of the products is within the quality control standards then the cleanup step can be eliminated.

- Light-to-dark batch sequencing. The scheduling of the batches in such a way that light paints are produced before dark paints could mean the elimination of an intermediate cleaning step in some cases.

- Prevent paint drying in the tanks. Cleaning the tanks immediately after use prevents scaling due to paint drying. This also reduces cleanup. Though a quart of solvent is poured into the tank to prevent drying, the tanks may be left unused long enough for this quantity to evaporate. Proper coordination between production and cleaning can prevent such occurrences.

- Computerized inventory control. There are several commercially available computerized inventory systems. Installation of these systems can improve the raw material tracking and help identify and remedy raw material losses at an early stage.

- Computerized waste documentation and control. Computerized waste documentation and control can help track the wastes in the process and can help in undertaking control strategies. Companies offering such systems (hardware and software) include Waste Documentation and Control Inc., in Beaumont, Texas, and Intellus Corporation in Irvine, California.

Other Waste Categories

After equipment cleaning wastes, important waste categories are: obsolete products, returns from customers, off-specification products, spills, filter bags and cartridges, and empty bags and cartridges. Recommended ways of reducing these wastes are as follows:

Obsolete Products

- Proper planning and inventory control. Obsolete stock can be minimized by proper planning and inventory control. Currently, the inventory check is done twice a year. By having a computerized inventory system, the inventory can be checked more frequently and overstocking, to some degree, can be reduced.

Returns from Customers

- Customer incentive programs. When customers return unused paint, the paint is reworked into other products, and the containers are cleaned. Customers that purchase large volumes of paint in drums could be offered cost incentives to convert to bulk purchase (e.g. 400 gallon Tote drums). This would reduce the quantity of returned drums that require cleaning at Plant B and would also result in reduction of residuals. The size of the containers used by Plant B's clientele can be controlled to some extent with similar incentive programs, if the cost savings in cleaning are significant.

Off-Specification Products

- Ensure proper batch formulation. Before making a batch, it is a current practice to attempt the formulation at a small scale in Plant B's labs. When large batches of paint are made, the lab scale formulations must be repeated two to three times to ensure that the formulation is correct. This prevents a large volume batch from becoming spoiled.

Spills

- Improved training and supervision. Proper equipment maintenance can prevent leaks, and increased training and closer supervision can prevent overfilling and spills during manual transfer.

- Discourage dry cleanup methods. Dry cleanup with solid adsorbents is widely used at Plant B for dealing with spills. Dry cleanup produces spent adsorbent waste that is not amenable to rework and thus needs to be disposed. Therefore, dry cleanup should be avoided to the extent possible, if the scooped up spills can be reworked.

Filter Bags and Cartridges

- Use bag filters in place of cartridges. Plant B

uses two cartridge filtration units, each containing six cartridges. Disposal of the spent filter cartridges is an anticipated problem. Cartridge filters can be replaced by bag filters. Spent bag filters contain much less paint than spent cartridges and can be reused several times; however, bag filters are more expensive. Unreusable bag filters can easily be washed with solvent and dried prior to their disposal as non-hazardous waste. Wash solvent can be combined with other solvent wastes and sent for off-site reclamation.

Use of wire screens in place of filter bags/ cartridges. Wire screens can be reused almost indefinitely when backwashed with a solvent and therefore are preferred to bags/cartridges. The backwashing process may generate a solvent-bearing waste. Therefore, the use of wire screens is recommended only if this waste stream can be reused or reworked on-site. Plant B already uses wire screen filters in two of the eight filtration units and is currently testing wire screen filters to replace the remaining filters.

Empty Bags and Packages

- Use of rinseable/recyclable drums. Replacement of bags and packages (used for hazardous materials) with rinseable/recyclable drums can be addressed through inquiries with suppliers.
- Use of pigments in slurry form. The availability of pigments in slurry form should be explored through vendor contacts. The use of pigments in slurry form means a reduction in waste bags and packages. The pigment slurry can be bought in drums or bulk form and the drums could be returned to the vendor.
- Segregation of empty bags and packages. Currently, all the empty bags and packages are baled and disposed of as hazardous waste, even though only some of the bags and packages contain hazardous material. Segregating the bags and packages containing hazardous pigments (lead or chromate) from those that do not contain hazardous materials would prevent the rest of the bags and packages from being considered hazardous.

RECYCLING AND RESOURCE RECOVERY MEASURES

The following recycling and resource recovery measures were considered for the facility:

- Increase recyclability
- On-site recycling
- Off-site recycling
- Waste exchange possibilities

Each of these measures is discussed in detail in the following paragraphs.

Increase Recyclability

Maintenance of minimum solvent content in the waste

The spent solvent from Plant B is sent to an off-site recycler for reclamation/incineration. The off-site recycler reclaims the solvent (at a net cost of $1.40/gal) only if the solvent yield from the waste is more than 60 percent. If the solvent yield is lower, the wastes are incinerated at a cost of $1.00/ gal. Incineration has an additional cost associated with the lost solvent that needs to be replaced ($ 1.57/gal for MEK). It is economically beneficial to generate a waste containing more than 60 percent solvent, if off-site reclamation is the preferred method. This creates an interesting constraint on all efforts aimed at reducing solvent use at the facility; the amount of solvent that ends up as a waste destined for off-site reclamation must be reduced together with the amount of solids that such a waste contains, e.g. by reducing clingage prior to cleaning or by improved caustic wash. Also, the amount of solvent evaporated during miscellaneous operations must be reduced.

Segregation of the solvent wastes

Recyclability is improved by segregation of the wastes. Segregation of cleanup wastes containing MEK and lacquer thinner should be tried in order to improve the recyclability of both streams. Another alternative involves using only one solvent (MEK or lacquer thinner) for all cleaning purposes. This generates a larger, single waste stream that is easier to handle.

On-site Recycling

On-site distillation

Plant B has attempted on-site reclamation using a solvent recovery still. This method, however, proved unprofitable in the past and was discontinued. This method should be reconsidered in light of the present disposal costs.

Reuse of cleanup solvent

Reuse of the cleanup solvent to the fullest extent possible can reduce waste solvent quantity. Wash solvent from each (or at least the most prevailing type) of solvent-based paint batches can be collected and segregated to facilitate reuse. The wash solvent can then be reworked into compatible batches. One example of such reuse is presented below.

The mills used for primary dispersion are cleaned by rinsing with solvent. The rinse solvent is added to the let-down tank only if let-down is the immediate next step in the process. Sometimes the dispersed pigments from the primary dispersion are sent for intermediate storage. In such cases, the rinse solvent is drummed for disposal and sent to an off-site recycler. The rinse solvent can be saved in a separate container and then added to the let-down when the compatible batch of dispersed pigments from intermediate storage is being processed in the let-down tank.

Rework cleanup solvents into useful products

Cleanup solvents from various cleaning operations can be blended and reworked into a marketable product. This method was attempted with success by one firm to produce a primer product.

Rework wastes

All of the wastes due to customer returns, obsolete finished products, off-specification products, and scooped up spills should be reworked to the fullest extent possible. This is already being practiced to some extent at Plant B.

Reuse of filter bags

The filter bags can be rinsed clean and reused several times. This is already practiced to some extent at Plant B. Such reuse will decrease the volume of spent filter bags that require disposal.

Off-site Recycling

Off-site recycling is already in effect at Plant B. The recycler reclaims and returns the solvent from the wastes if the solvent yield from the wastes is more than 60 percent. However, cost increases are anticipated because of the increasing cost of insurance to the recycler.

Waste Exchange Possibilities

Information about Waste Exchanges is included in the following Appendix section: Where to Get Help.

RATING AND SCREENING OF WASTE MINIMIZATION MEASURES

Table A-9 lists the various source reduction measures noted for each waste stream. Table A-10 lists the recycling and resource recovery options. Each measure is rated on a scale of 0 (low) to 10 (high) for its waste reduction effectiveness, extent of current use, and future application potential. The waste reduction effectiveness indicates the amount of waste reduction that is possible by implementing a particular source reduction/recycle measure. The extent of current use, as the name implies, is a measure of current usage of a particular waste reduction option. The future application potential is a qualitative measure of how easy it would be to implement, considering cost and technical feasibility.

According to facility personnel, the most effective source reduction measure for reducing equipment cleanup wastes was caustic sludge dewatering. This method would require the installation of equipment for dewatering. Other source reduction methods considered effective by the facility personnel for dealing with equipment cleanup wastes were avoidance of unnecessary cleaning, replacement of caustic cleaning solution, and prevention of paint drying in tanks.

The following source reduction methods for dealing with other specific waste streams were given high ratings by the facility personnel:

- Proper planning and inventory control for obsolete stock;
- Customer incentive programs for customer returns;
- Ensuring proper batch formulation for off-specification products;
- Improved training and supervision for handling of spills;
- Use of bag filters in place of cartridges;
- Use of wire screen filters in place of bag/cartridge filters; and
- Use of rinseable and recyclable drums for empty bags or packages.

Among the recycling and resource recovery options, reconsideration of on-site distillation received the highest rating of 8. This measure would involve the installation of a distillation unit. Other recycling/resource recovery measures rated highly include reuse of spent solvent, rework of various waste streams, and the segregation of solvent waste streams to promote their recyclability.

Feasibility Analysis Phase

After discussions with Plant B personnel, some of the options discussed in the previous section were selected for investigation of their technical and economic feasibility. The economic analysis was based on the raw material and waste disposal costs provided by the facility personnel and on economic and technical information provided by equipment manufacturers. The measures evaluated in this section include: use of on-site distillation for solvent recovery, caustic sludge dewatering, replacement of caustic cleaning solution, avoidance of unnecessary cleaning, replacement of cartridges with bag filters, and replacement of cartridge or bag filters with wire mesh filters. Other

Table A-9. Summary of Source Reduction Measures for Plant B.

Waste Source		Control Methodology	Waste Reduction Effectiveness	Extent of Current Use	Future Application Potential	Current Reduction Index	Future Reduction Index
Equipment Cleaning Wastes	1.	Raw Material substitution.	9	9	2	8	0
	2.	Improved production planning.	6	6	5	4	1
	3.	Recirculation through the mill.	2	0	2	0	0
	4.	Replacement of caustic solution.	5	0	5	0	3
	5.	Caustic wash sludge dewatering.	7	0	5	0	4
	6.	Mechanical Cleaning.	5	5	5	3	1
	7.	High-pressure nozzle replacement.	5	5	5	3	1
	8.	Replacement of existing mills.	2	2	2	0	0
	9.	High-pressure clean stationary tanks.	2	2	2	0	0
	10.	Avoidance of unnecessary cleaning.	8	5	7	4	3
	11.	Light-to dark batch sequencing.	5	5	5	3	1
	12.	Prevent paint drying in the tanks.	5	3	5	2	2
	13.	Computerized inventory control.	5	3	5	2	2
	14.	Computerized waste documentation.	5	0	5	0	3
Obsolete Products	1.	Proper planning & inventory control.	5	3	7	2	2
Customer Returns	1.	Customer incentive programs.	6	2	2	1	1
Off-Spec Products	1.	Ensure proper batch formulation.	6	4	6	2	2
Spills	1.	Improved training and supervision.	6	4	6	2	2
		2. Discourage dry cleanup methods.	7	7	7	5	1
Filter Cartridges	1.	Use bags instead of cartridges.	7	4	6	3	3
	2.	Use wire screen filters.	7	3	8	2	4
Empty bags & Packages	1.	Use of rinseble/recyclable drums.	6	0	2	0	1
	2.	Use of pigments in slurry form.	6	2	5	1	2

Table A-10. Summary of Recycling and Resource Recovery Measures for Plant B.

Waste Source	Control Methodology	Waste Reduction Effectiveness	Extent of Current Use	Future Application Potential	Current Reduction Index	Future Reduction Index
Increase Recyclability	1. Maintain minimum solvent in waste.	5	5	5	3	1
	2. Segregation of the wastes.	6	4	6	2	2
On-Site Recycling	1. Reconsider on-site distillation unit.	9	0	9	0	8
	2. Reuse of cleaning solvent.	7	3	7	2	3
	3. Rework of cleanup solvent.	6	4	7	2	3
	4. Rework wastes.	6	4	7	2	3
	5. Reuse filter bags.	5	5	5	3	1
Off-site Recycling	1. Off-site reclamation /incineration.	7	7	4	5	1
Waste Exchange	1. Off-site reuse.	3	0	3	0	1

options, such as reuse of cleaning solvent and rework of various waste streams, are to be examined by Plant B for their technical feasibility. Since these measures involve more efficient use of the materials, the economic benefits are obvious.

On-site Distillation

On-site distillation was attempted in the past at Plant B and was discontinued as it proved unprofitable. But present disposal costs and their expected increases justify a re-examination of this option. The following conditions must be satisfied for the distillation still to be purchased and installed:

- The still should meet the technical requirements for reclaiming the solvents;
- The economics of on-site distillation must be proven to be favorable; and
- The measure should be proven to be an environmentally safer option (short term and long term) compared to the presently employed off-site recycling.

The total waste sent to the off-site recycler in 1985 is 223.5 tons/yr, which amounts to 44,700 gal/yr (assuming a density of 10 lb/gal). Assuming a one shift operation and a 5 day work week, a maximum of 2,080 hrs/yr of onstream time is available. This results in a minimum throughput of 21.5 gal/hr. Using a conservative estimate of 5 hours per batch, a batch capacity of 100 gallons is recommended. For a base case analysis, the economics of using the Progressive Recovery Inc. (PRI) Model SC-400, which has a batch capacity of 120 gallons, is presented in Table A-11.

Based on the analysis presented in Table A-11 the installation of an on-site still appears to be economically attractive since it has a payback period of 1.9 years, and, as such, is much less than the (rule-of-the-thumb) hurdle rate of 3 years. As this economic analysis does not consider the major price hikes contemplated by the recycler, the on-site distillation option has an even greater economic appeal.

The technical feasibility of on-site distillation can be examined by sending a solvent waste sample to PRI. The reclaimed solvent and the distillation residues returned by PRI can be examined by Plant B for the distillate yield and the quality of recovered solvent. PRI's equipment has been used to handle paint process wastes at other facilities and is therefore expected to meet the requirements of Plant B.

On-site reclamation has the following benefits:

- The transportation of the wastes and the associated risks are minimized because less waste leaves the facility;
- Plant B has more control over the purity of the reclaimed solvent;
- Even though the distillation residues require off-site incineration, the disposal costs will be less affected by increases in charges by off-site recyclers, because the waste volume is considerably reduced;
- It is cheaper to recover on-site; and
- On-site reclamation is not considered treatment by RCRA and therefore does not require a TSDF status to be obtained by the facility.

Table A-11. Economics of On-Site Distillation

Installation Costs	
Capital cost, still, PRI Model SC-400 with autofill and cycle complete shutoff	$ 32,150
Freight Cost (a)	1,930
Tax (b)	2,090
Installation (labor plus supplies), 50 ft. of 1" pipe for cooling water and two explosion-proof conduits	3,500
Total Installed Cost	$ 39,670
Current Annual Disposal Costs	
Recycling costs @ $130/ton	29,055
Surcharge for disposal of distillation residues @ $150/ton	33,525
Total Disposal Costs	$ 62,580
Annual Incremental Savings	
Lost raw material costs (c)	6,980
Disposal costs (d)	44,610
Labor (e)	- 18,720
Other (utilities) (f)	- 12,023
Savings	$ 20,847
Pay back period, years	1.9

(a) Estimated as 6 % of capital cost
(b) 6.5 % sales tax
(c) The solvent is assumed to be MEK.
(d) Incineration of distillation residues @ $200/ton assumed, and a 90 % solvent recovery process. The disposal cost of distillation residues is $ 17,970.
(e)Estimated for 40 hr/wk @ $9.00/hr.
(f)Based on a still operating cost of $0.30/gal of recovered solvent.

The disadvantages of on-site reclamation are:

- Capital investment needed for the still
- Additional operating costs
- Possible need for operator training
- Air quality permits may be needed to operate the equipment

- Landfill disposal option for distillation bottoms is probably not available, as it is doubtful that residues will pass the new TCLP test requirements (Nov. 8, 1986 landfill ban regulations). This leaves only the incineration option.
- Liability and risks due to improper equipment operation or solvent quality maintenance are incurred.

Because distillation bottoms can be incinerated off-site, environmental and regulatory concern do not play as big a role in the decision to convert to on-site reclamation as do economics.

Caustic Sludge Dewatering

Alkaline cleaning of portable tanks produces a sludge that is sent to the off-site recycler for incineration. This sludge contains a significant amount of alkaline solution. Dewatering will decrease the sludge volume, reducing disposal costs. At present, 13.2 tons/yr of sludge is disposed of at a cost of $1.00/gal through an off-site recycler. Assuming the density of 10 lb/gal for the sludge, this represents an annual disposal cost of $ 2,640. Assuming that the sludge contains 10 percent of solids, and that dewatering produces sludge with 30% solids, a savings of $ 1,770/yr can be achieved. The operating costs of a dewatering unit were not subtracted from these savings. Small savings such as these do not seem to warrant the purchase of even a not-very-efficient filtration unit. In addition, the environmental benefits of dewatering are questionable. The recovered aqueous portion will need additional treatment such as neutralization before discharge to the sewer. Therefore, caustic sludge dewatering is not expected to have any significant economic or environmental impact.

Replacement of Caustic Cleaning Solution

The presently used caustic cleaning solution could be replaced with more efficient commercially available alkaline cleaning agents. Based on the experience of a different facility, a 50 percent reduction in cleaning solution replacement is expected. This translates roughly into a reduction of 50 percent in sludge waste volume, or a savings of about $ 1,320/yr. The increase in the purchase cost of the cleaning solution should be lower than this amount to justify substitution. In addition, the effectiveness of the new cleaning solution would need to be demonstrated on a trial basis.

Avoidance of Unnecessary Cleaning

The technical feasibility of eliminating a cleanup step can be established by examining its effect on product quality in a lab scale experiment. If product contamination is within quality control standards of the facility, the cleanup step can be eliminated. This option does not involve any capital investment. If avoiding unnecessary cleaning can result in a decrease of 10 percent in waste volume, about $6,000/yr in present disposal costs would be saved.

Replace Cartridges with Bag Filters

Plant B uses cartridges in two filtration units, each containing six cartridges. To use bag filters in place of cartridges, one possibility is the purchase of 12 new filter housings. Other possibilities include the purchase of two housings, each containing six bag filters. As an example, Table A-12 presents the economics of replacing cartridge filters with bag filters in 12 new housings. The payback period is 7.4 years and therefore the option is not considered viable. The use of two filter housings, each holding six filters (with total capital cost of $ 20,000) does not seem to significantly reduce the payback period. In addition, the technical feasibility of using bag filters in place of cartridges must be established through trial runs.

Table A-12. Economics of Replacing Cartridge Filters with Bag Filters

Installed Cost	
Filter housings (12), delivered cost including tax and freight	$ 20,950
Installation including labor and supplies	3,000
Total Installed Cost	$ 23,950
Annual Incremental Savings	
Raw materials, solvents (a)	470
Disposal costs (b)	2,770
Operating costs (c)	0
Savings	$ 3,240
Payback period, years	7.4

(a)Assuming no solvent retention in bag filters.

(b)It is assumed that the cartridge filters are replaced 12 times/week. Using bag filters in their place reduces volume of solid waste by 6.0 ft3/wk. Current disposal fee is assumed to be $9.25/ft3.

(c)The bags are replaced 3 times/wk at $12/bag and the cartridges are replaced 12 times/wk at $3/cartridge.bag filters in place of cartridges must be established through trial runs.

Replace Cartridges and Bag Filters with Wire Mesh Filters

Plant B uses four bag filter units and 12 cartridge filter units. The wire screen filters can be reused almost indefinitely because they are backwashable. Therefore, this measure could eliminate the spent filter bag/cartridge

waste. Table A-13 presents the economics of replacing these with wire mesh screens. The increase in disposal costs associated with the solvent-bearing waste from back-washing is not considered to be significant in this analysis. Such a waste can be combined with other solvent wastes destined for reclamation. As seen from Table A-13 the payback period for implementing this measure is 0.2 years. Plant B is already testing the effectiveness of some wire mesh filters. If the technical requirements are met, it is recommended that wire mesh filters replace bag/cartridge filters.

Table A-13. Economic Aspects of Replacing Bag or Cartridge

FILTERS WITH WIRE MESH FILTERS

Installed Costs

Metal mesh filters (16), delivered cost including sales tax	$ 2,550
Installation, including labor and supplies	4,000
Total Installed Costs	$ 6,550

Annual Incremental Savings

Raw material, solvents (a)	470
Disposal costs (b)	2,775
Labor (c)	0
Other (cartridges,bags) (d)	$ 28,800
Total Savings	$ 32,045
Payback Period, years	0.2

(a)Based on 1 ton/yr loss of solvent (MEK)

(b)Based on reducing the volume of solidified waste by 6.0 ft3/wk. Current disposal fee is $9.25/ft3.

(c)Assuming that the change in labor costs is not significant.

(d)Based on the use of 144 cartridges/wk at $3.00/cartridge and 12 bags/wk at $12.00/bag.

Summary and Discussion

Plant B's major source of waste generation is the equipment cleaning operation. A number of waste minimization options to reduce, reuse, or recycle each of the wastes was identified. After rating the options, the following were chosen for additional economic analysis:

- on-site distillation
- caustic sludge dewatering
- replacement of caustic cleaning solution
- avoidance of unnecessary cleaning
- replacement of cartridges with bag filters
- replacement of cartridges and bags with wire screen filters

The equipment cleaning wastes can be distilled on-site at an annual savings of about $21,000. The payback period for installation of an automatic still is 1.9 years, which makes this option economically attractive. Other measures considered to have good potential are avoidance of unnecessary cleaning and replacement of caustic cleaning solution.

Caustic sludge dewatering, though effective in decreasing waste volume, is not recommended because the environmental and economic benefits do not seem significant enough to warrant capital investment. Replacement of cartridges with bag filters has a payback period of about 7.4 years and is therefore not a viable option. However, replacement of bags or cartridges with wire screen filters has a payback period of 0.2 years and therefore is highly attractive if the technical requirements are met.

On-site distillation appears to be economically feasible and to offer significant waste reduction potential; however, its technical feasibility needs to be established. Also, the technical feasibility of using wire screen filters in place of bag or cartridge filters needs to be established.

APPENDIX B
WHERE TO GET HELP
FURTHER INFORMATION ON POLLUTION PREVENTION

Additional information on source reduction, reuse and recycling approaches to pollution prevention is available in EPA reports listed in this section, and through state programs (listed below) that offer technical and/or financial assistance in the areas of pollution prevention and treatment.

In addition, waste exchanges have been established in some areas of the U.S. to put waste generators in contact with potential users of the waste. Four waste exchanges are listed below. Finally, EPA's regional offices are listed.

EPA REPORTS ON WASTE MINIMIZATION

U.S. Environmental Protection Agency. "Waste Minimization Audit Report: Case Studies of Corrosive and Heavy Metal Waste Minimization Audit at a Specialty Steel Manufacturing Complex." Executive Summary.*

U.S. Environmental Protection Agency. "Waste Minimization Audit Report: Case Studies of Minimization of Solvent Waste for Parts Cleaning and from Electronic Capacitor Manufacturing Operation." Executive Summary.*

U.S. Environmental Protection Agency. "Waste Minimization Audit Report: Case Studies of Minimization of Cyanide Wastes from Electroplating Operations." Executive Summary.*

U.S. Environmental Protection Agency. *Report to Congress: Waste Minimization, Vols. I and II.* EPA/530-SW-86-033 and -034 (Washington, D.C.: U.S. EPA, 1986).**

U.S. Environmental Protection Agency. *Waste Minimization - Issues and Options, Vols. I-III* EPA/530-SW-86-041 through -043. (Washington, D.C.: U.S. EPA, 1986).**

* Executive Summary available from EPA, WMDDRD, RREL, 26 West Martin Luther King Drive, Cincinnati, OH, 45268; full report available from the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA 22161.

** Available from the National Technical Information Service as a five-volume set, NTIS No. PB-87-114-328.

WASTE REDUCTION TECHNICAL/FINANCIAL ASSISTANCE PROGRAMS

The EPA's Office of Solid Waste and Emergency Response has set up a telephone call-in service to answer questions regarding RCRA and Superfund (CERCLA):

(800) 242-9346 (outside the District of Columbia)

(202) 382-3000 (in the District of Columbia)

The following states have programs that offer technical and/or financial assistance in the areas of waste minimization and treatment.

Alabama
Hazardous Material Management and Resources Recovery Program
University of Alabama
P.O. Box 6373
Tuscaloosa, AL 35487-6373
(205) 348-8401

Alaska
Alaska Health Project
Waste Reduction Assistance Program
431 West Seventh Avenue, Suite 101
Anchorage, AK 99501
(907) 276-2864

Arkansas
Arkansas Industrial Development Commission
One State Capitol Mall
Little Rock, AR 72201
(501) 371-1370

California
Alternative Technology Section
Toxic Substances Control Division
California State Department of Health Service
714/744 P Street
Sacramento, CA 94234-7320
(916) 324-1807

Connecticut
Connecticut Hazardous Waste Management Service
Suite 360
900 Asylum Avenue
Hartford, CT 06105
(203) 244-2007

Connecticut Department of Economic Development
210 Washington Street
Hartford, CT 06106
(203) 566-7196

Georgia
Hazardous Waste Technical Assistance Program
Georgia Institute of Technology
Georgia Technical Research Institute
Environmental Health and Safety Division
O'Keefe Building, Room 027
Atlanta, GA 30332
(404) 894-3806

Environmental Protection Division
Georgia Department of Natural Resources
Floyd Towers East, Suite 1154
205 Butler Street
Atlanta, GA 30334
(404) 656-2833

Illinois
Hazardous Waste Research and Information Center
Illinois Department of Energy of Energy and Natural Resources
1808 Woodfield Drive
Savoy, IL 61874
(217) 333-8940

Illinois Waste Elimination Research Center
Pritzker Department of Environmental Engineering
Alumni Building, Room 102
Illinois Institute of Technology
3200 South Federal Street
Chicago, IL 60616
(313) 567-3535

Indiana
Environmental Management and Education Program
Young Graduate House, Room 120
Purdue University
West Lafayette, IN 47907
(317) 494-5036

Indiana Department of Environmental Management
Office of Technical Assistance
P.O. Box 6015
105 South Meridian Street
Indianapolis, IN 46206-6015
(317) 232-8172

Iowa
Center for Industrial Research and Service
205 Engineering Annex
Iowa State University
Ames, IA 50011
(515) 294-3420

Iowa Department of Natural Resources
Air Quality and Solid Waste Protection Bureau
Wallace State Office Building
900 East Grand Avenue
Des Moines, IA 50319-0034
(515) 281-8690

Kansas
Bureau of Waste Management
Department of Health and Environment
Forbes Field, Building 730
Topeka, KS 66620
(913) 269-1607

Kentucky
Division of Waste Management
Natural Resources and Environmental Protection Cabinet
18 Reilly Road
Frankfort, KY 40601
(502) 564-6716

Louisiana
Department of Environmental Quality
Office of Solid and Hazardous Waste
P.O. Box 44307
Baton Rouge, LA 70804
(504) 342-1354

Maryland
Maryland Hazardous Waste Facilities Siting Board
60 West Street, Suite 200 A
Annapolis, MD 21401
(301) 974-3432

Maryland Environmental Service
2020 Industrial Drive
Annapolis, MD 21401
(301) 269-3291
(800) 492-9188 (in Maryland)

Massachusetts
Office of Safe Waste Management
Department of Environmental Management
100 Cambridge Street, Room 1094
Boston, MA 02202
(617) 727-3260

Source Reduction Program
Massachusetts Department of Environmental Quality Engineering
1 Winter Street
Boston, MA 02108
(617) 292-5982

Michigan
Resource Recovery Section
Department of Natural Resources
P.O. Box 30028
Lansing, MI 48909
(517) 373-0540

Minnesota
Minnesota Pollution Control Agency
Solid and Hazardous Waste Division
520 Lafayette Road
St. Paul, MN 55155
(612) 296-6300

Minnesota Technical Assistance Program
W-140 Boynton Health Service
University of Minnesota
Minneapolis, MN 55455
(612) 625-9677

(800) 247-0015 (in Minnesota)
Minnesota Waste Management Board
123 Thorson Center
7323 Fifty-Eighth Avenue North
Crystal, MN 55428
(612) 536-0816

Missouri
State Environmental Improvement and Energy
Resources Agency
P.O. Box 744
Jefferson City, MO 65102
(314) 751-4919

New Jersey
New Jersey Hazardous Waste Facilities Siting
Commission
Room 614
28 West State Street
Trenton, NJ 08608
(609) 292-1459
(609) 292-1026

Hazardous Waste Advisement Program
Bureau of Regulation and Classification
New Jersey Department of Environmental
Protection
401 East State Street
Trenton, NJ 08625

Risk Reduction Unit
Office of Science and Research
New Jersey Department of Environmental Protection
401 East State Street
Trenton, NJ 08625

New York
New York State Environmental Facilities
Corporation
50 Wolf Road
Albany, NY 12205
(518) 457-3273

North Carolina
Pollution Prevention Pays Program
Department of Natural Resources and
Community Development
P.O. Box 27687
512 North Salisbury Street
Raleigh, NC 27611
(919) 733-7015

Governor's Waste Management Board
325 North Salisbury Street
Raleigh, NC 27611
(919) 733-9020

Technical Assistance Unit
Solid and Hazardous Waste Management Branch
North Carolina Department of Human Resources
P.O. Box 2091
306 North Wilmington Street
Releigh, NC 27602
(919) 733-2178

Ohio
Division of Solid and Hazardous Waste Management
Ohio Environmental Protection Agency
P.O. Box 1049
1800 WaterMark Drive
Columbus, OH 43266-1049
(614) 481-7200

Ohio Technology Transfer Organization
Suite 200
65 East State Street
Columbus, OH 43266-0330
(614) 466-4286

Oklahoma
Industrial Waste Elimination Program
Oklahoma State Department of Health
P.O. Box 53551
Oklahoma City, OK 73152
(405) 271-7353

Oregon
Oregon Hazardous Waste Reduction Program
Department of Environmental Quality
811 Southwest Sixth Avenue
Portland, OR 97204
(503) 229-5913

Pennsylvania
Pennsylvania Technical Assistance Program
501 F. Orvis Keller Building
University Park, PA 16802
(814) 865-0427

Center of Hazardous Material Research
320 William Pitt Way
Pittsburgh, PA 15238
(412) 826-5320

Bureau of Waste Management
Pennsylvania Department of
Environmental Resources
P.O. Box 2063
Fulton Building
3rd and Locust Streets
Harrisburg, PA 17120
(717) 787-6239

Rhode Island
Ocean State Cleanup and Recycling Program
Rhode Island Department of Environmental Management
9 Hayes Street
Providence, RI 02908-5003
(401) 277-3434
(800) 253-2674 (in Rhode Island)

Center for Environmental Studies
Brown University
P.O. Box 1943
135 Angell Street
Providence, RI 02912
(401) 863-3449

Tennessee
Center for Industrial Services
102 Alumni Hall
University of Tennessee
Knoxville, TN 37996
(615) 974-2456

Virginia
Office of Policy and Planning
Virginia Department of Waste Management
11th Floor, Monroe Building
101 North 14th Street
Richmond, VA 23219
(804) 225-2667

Washington
Hazardous Waste Section
Mail Stop PV-11
Washington Department of Ecology
Olympia, WA 98504-8711
(206) 459-6322

Wisconsin
Bureau of Solid Waste Management
Wisconsin Department of Natural Resources
P.O. Box 7921
101 South Webster Street
Madison, WI 53707
(608)267-3763

Wyoming
Solid Waste Management Program
Wyoming Department of Environmental Quality
Herchler Building, 4th Floor, West Wing
122 West 25th Street
Cheyenne, WY 82002
(307) 777-7752

WASTE EXCHANGES

Northeast Industrial Exchange
90 Presidential Plaza, Syracuse, NY 13202
(315) 422-6572

Southern Waste Information Exchange
P.O. Box 6487, Tallahassee, FL 32313
(904) 644-5516

California Waste Exchange
Department of Health Services
Toxic Substances Control Division
Alternative Technology & Policy Development Section
714 P Street
Sacramento, CA 95814
(916) 324-1807

U.S. EPA REGIONAL OFFICES

Region 1 (VT, NH, ME, MA, CT, RI)
John F. Kennedy Federal Building
Boston, MA 02203
(617) 565-3715

Region 2 (NY, NJ)
26 Federal Plaza
New York, NY 10278
(212) 264-2525

Region 3 (PA, DE, MD, WV, VA)
841 Chestnut Street
Philadelphia, PA 19107
(215) 597-9800

Region 4 (KY, TN, NC, SC, GA, FL, AL, MS)
345 Courtland Street, NE
Atlanta, GA 30365

(404) 347-4727

Region 5 (WI, MN, MI, IL, IN, OH)
230 South Dearborn Street
Chicago, IL 60604
(312) 353-2000

Region 6 (NM, OK, AR, LA, TX)
1445 Ross Avenue
Dallas, TX 75202
(214) 655-6444

Region 7 (NE, KS, MO, IA)
756 Minnesota Avenue
Kansas City, KS 66101
(913) 236-2800

Region 8 (MT, ND, SD, WY, UT, CO)
999 18th Street
Denver, CO 80202-2405

(303) 293-1603

Region 9 (CA, NV, AZ, HI)
215 Fremont Street
San Francisco, CA 94105
(415) 974-8071

Region 10 (AK, WA, OR, ID)
1200 Sixth Avenue
Seattle, WA 98101
(206) 442-5810

* U.S. Government Printing Office: 1990-768-159/00682

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

BULK RATE
POSTAGE & FEES PAID
EPA
PERMIT No. G-35

Official Business
Penalty for Private Use, $300

Please make all necessary changes on the above label, detach or copy, and return to the address in the upper left-hand corner.

If you do not wish to receive these reports CHECK HERE ☐, detach, or copy this cover, and return to the address in the upper left-hand corner.

EPA 625 7-90 005